The Development of American Industries

The Development of American Industries

Their Economic Significance

PLANNED AND EDITED BY

John George Glover, M.C.S., Ph.D.
Professor of Management
School of Commerce, Accounts and Finance
New York University

AND

William Bouck Cornell, M.E.
Professor of Management and Chairman of the Department of Management and Ind trial Relations, School of Commerce, Accounts and Finance, New York University
Member, American Society of Mechanical Engineers, Institute of Management and American Management Association

WITH A FOREWORD BY

John T. Madden, A.M., M.C.S., C.P.A.
Dean, School of Commerce, Accounts and Finance
New York University

Revised Edition

New York: 1946
PRENTICE-HALL, INC.

Preface to the Revised Edition

Since *The Development of American Industries* was first published in 1932, social, economic, and business changes have made a revision necessary. Statistics have been brought up to date, changes in the status of industries have been explained, the effects of legislative enactments have been stressed, changes in methods of production have been discussed, and new products have been described.

The effect of war conditions abroad and of our own national defense program has not been unduly emphasized. The final outcome of the Second World War, the amount of disruption of industry, the new products and new methods that will have to be developed to meet emergency conditions, and the effect of the heavy tax program to cover national deficits are all factors that will have to be known before anything can be written that will be more than a matter of opinion or surmise.

JOHN G. GLOVER
WILLIAM B. CORNELL

Foreword to the First Edition

It is particularly appropriate that this volume, devoted to a history of American industry, is issued upon the occasion of the 100th Anniversary of the founding of New York University. Most of the founders were men of affairs, leaders in the financial and business life of the city. They had a vision of the important rôles which science and industrial organization were to play in the development of our country. Although the University did not at all times follow strictly the course laid out by its founders, nevertheless it did contribute greatly to the scientific and industrial progress of the nation.

It should now be evident that scientific progress and industrial organization are the foundations upon which the structure of our future social life must rest. We have passed out of a scarcity economy into an era of surplus economy, and the future well-being of the people of all nations depends largely—one might almost say, principally—upon the more perfect working of industrial organization.

In these pages is unfolded the thrilling story of the development of American industry. The management of this tremendous force involving an investment of one hundred billion dollars must not be entrusted to men who have not developed a sense of their social responsibility. We need as never before an intelligent citizenship possessing all the culture which has come down to us as a heritage of the past but capable of building a new culture which shall have its roots in a new soil—science and industrial organization. This does not imply retrogression. On the contrary, it means an expansion of cultural opportunities with accompanying social adjustments of profound significance.

The culture of Athens was based upon the trade and commerce of Athens. The Romans appropriated freely from the Greeks and by adding their contributions of law and government prepared the road for the greatest adjustment of all—our Christian civilization. The new social force, preserving the heritage of all preceding movements, shall through science and industry carry forward our culture, our social welfare and human happiness to still higher planes. Perhaps the true philosopher only is conscious as yet of the revolution through which we are passing, but this history of American industry will serve in a measure at least to prepare the background for more serious study and reflection.

JNO. T. MADDEN

Preface to the First Edition

The unprecedented growth of American industries has been due largely to American inventive genius in developing processes and methods for converting our vast natural resources into usable commodities and to the enterprise of far-sighted business men who have taken advantage of economic opportunities. Through their efforts and the enterprise of the industries they represent, our standards of living have been raised far above those of other nations. In order to appreciate the significance of our advanced civilization, it is necessary to understand its industrial background and to examine the history of the development of the major American industries and their phenomenal growth over the past two centuries.

To secure the material for such a study would involve the reading of many volumes and the making of infinite inquiry among industries, as much of the information needed has never been in print up to this time. The average student of pure arts and sciences and of business would not have the opportunity, facilities, or desire for such an exhaustive study. Much less would the man of experience have the time or opportunity. To meet this need and the need of the teachers who lack the time for such exhaustive research, this book has been written.

An authoritative and adequate treatment of such a broad subject—the development of each of thirty-nine major industries—would not be within the mental or physical capabilities of any one or two persons. The coöperation of the industries themselves was therefore solicited. Prominent trade associations and leading industrial concerns became interested in the project. As a result, each chapter in the book is the joint product of some of the best minds in the particular industry covered, and is a scholarly and accurate history of the industry.

In general, each industry taken up in the text has been treated in a similar manner, not only to secure as far as possible a true cross-sectional representation of the industry itself, but also to permit of comparison between one industry and any other industry. Broadly speaking, the treatment of each industry covers its early history, including discoveries and operations, growth of the industry and the leaders in its field; the geographic location of important industrial centers; raw materials used; manufacturing methods; important products, including their volume, value and important uses, and by-products; methods of marketing, both domestic and foreign; methods of financing, and capital invested; labor—

the number and trades of people employed, health and safety conditions, etc.; internal organization of a typical company in the industry; important companies in the industry; legislation affecting the industry, and the possible future developments. One chapter has been devoted to each industry except the textile industry, which has been given two chapters for the reason that in covering this subject it seemed appropriate to include a brief discussion of the Industrial Revolution and the facts leading up to it, as well as to cover the textile industry itself.

This book has been developed primarily for use as a text in colleges of arts and sciences and in schools of commerce and business administration, and is the outgrowth of a course of lectures given over a period of several years in the School of Commerce, Accounts and Finance, New York University. However, inasmuch as many graduate engineers enter the production, selling, and financial field, it is hoped that the book will serve equally well as a text in schools of engineering. The treatment as covered in this book may often give the student a conception of an industry very different from that which he formerly held. Often it may aid the student in deciding as to the particular industry, and also as to what branch of that industry—production, selling or finance—he will enter upon graduation.

To the business man, the book should be of value in that it gives the history of the development and the economic significance today of many industries, and cites practices which may well be adapted to his own business. Articles appearing in periodicals and in our daily newspapers relating to tariff and other legislation, to strikes, wages, unemployment and economic conditions, and to business in general, should be of more significance to the reader due to the many points brought out in the volume.

In giving in one volume a history of thirty-nine industries and a perspective, historical and economic, of the United States from its beginning to the present, this book is in reality a history of industrial economy in the United States.

The editors wish to express their deep appreciation of the splendid coöperation given by the trade associations, industrial concerns, and executives who have helped them in their task. To them full credit is given for the manuscripts covering their respective industries. The names of these contributors are given in the table of contributors which follows.

John G. Glover
William B. Cornell

Table of Contributors

(Revised Edition)

6
THE PULP AND PAPER INDUSTRY
by
Dr. Charles W. Boyce
Executive Secretary
Kraft Paper Association

7
THE BOOK PUBLISHING INDUSTRY
by
Book Publishers Bureau, Inc.
S. P. Hunnewell
Executive Secretary

8
THE NEWSPAPER INDUSTRY
by
The New York Times*

9
THE TEXTILE INDUSTRY—COTTON FROM PREHISTORIC TIMES TO 1930
by
M. D. C. Crawford

10
THE MODERN TEXTILE INDUSTRY
by
Douglas G. Woolf
Editor-in-Chief, "The Textile World"

11
THE COTTON-GROWING INDUSTRY
by
Cotton Branch Experimental Station
of the
College of Agriculture
University of Arkansas
E. B. Whitaker
Assistant Director in Charge
Revised for 1941 edition by information from
United States Department of Agriculture

12
THE RUBBER INDUSTRY
by
The Rubber Manufacturers Association, Inc.
A. L. Viles
President

* This refers to the part of the chapter under the heading "A Modern Newspaper Plant," dealing with the production of a metropolitan newspaper today.

13
THE LEATHER INDUSTRY
by
The United States Leather Company
Roland H. Zinn
Vice President

14
THE SUGAR INDUSTRY
by
Louis A. Wills
Technologist
American Sugar Refining Company

15
THE PETROLEUM INDUSTRY
by
The Texas Corporation
W. S. S. Rodgers
President

16
THE COAL INDUSTRY
by
The American Mining Congress
Henry Mace Payne
Consulting Engineer
Revised for 1941 edition by information from United States Government publications

17
THE IRON AND STEEL INDUSTRY
by
The American Rolling Mill Company
Charles R. Hook
President
Hugh W. Wright
Assistant to Director of Personal Relations

18
THE COPPER INDUSTRY
by
Copper and Brass Research Association
T. E. Veltfort
Manager
B. B. Caddle
Secretary

19

THE LEAD INDUSTRY
by
Lead Industries Association
Felix Edgar Wormser
Secretary and Treasurer

20

THE ZINC INDUSTRY
by
American Zinc Institute, Inc.
Ernest V. Gent
Secretary

21

THE GLASS INDUSTRY
by
"American Glass Review"

22

THE PLATE GLASS INDUSTRY
by
Pittsburgh Plate Glass Company
R. A. Miller
Technical Sales Engineer

23

THE CEMENT INDUSTRY
by
Edison Cement Company
William Hildebrand
Vice President

24

THE CHEMICAL INDUSTRY
by
Monsanto Chemical Company
Robert L. Taylor

25

THE PAINT, VARNISH, AND LACQUER INDUSTRY
by
National Paint, Varnish and Lacquer Association, Inc.
Henry A. Gardner
Director, Scientific Section

26

THE MACHINE TOOL INDUSTRY
by
National Machine Tool Builders' Association
John E. Lovely
President
Frederick V. Geier
First Vice President
Tell Berna
General Manager

27

THE ELECTRICAL INDUSTRY
by
Westinghouse Electric and Manufacturing Company
William A. Dick

28

THE POWER INDUSTRY
by
Edison Electric Institute
William M. Carpenter
Economist

29

THE SHIPBUILDING AND SHIPPING INDUSTRY
by
National Council of American Shipbuilders
H. Gerrish Smith
President
C. C. Knerr
Secretary-Treasurer

30

THE RAILROAD INDUSTRY
by
New York Central Lines
F. E. Williamson
President

31

THE AUTOMOBILE INDUSTRY
by
Chrysler Corporation
T. J. Ross
Public Relations Counsel

32
THE AERONAUTICAL INDUSTRY
by
Curtiss-Wright Corporation
H. E. Lawrence
Director of Public Relations

33
THE TELEGRAPH INDUSTRY
by
The Western Union Telegraph Company
George P. Oslin
under the direction of
A. N. Williams
President

34
THE TELEPHONE INDUSTRY
Chapter written from historical,
statistical, and technical
information furnished by
American Telephone and Telegraph Company

35
THE MOTION PICTURE INDUSTRY
prepared in coöperation with the
Motion Picture Producers and
Distributors of America, Inc.
Will H. Hays
President

36
THE RADIO INDUSTRY
by
Radio Corporation of America
E. E. Bucher

37
THE RETAILING INDUSTRY
by
Dr. E. O. Schaller
School of Retailing, New York University

38
THE HOTEL INDUSTRY
by
American Hotel Association
Thomas D. Green
Executive Director

Table of Contents

TABLE OF CONTENTS

Table of Illustrations

THE MEAT PACKING INDUSTRY

THE FISHING INDUSTRY

THE LUMBER INDUSTRY

THE PULP AND PAPER INDUSTRY

Table of Illustrations

THE TEXTILE INDUSTRY

THE MODERN TEXTILE INDUSTRY

THE RUBBER INDUSTRY

PAGE

THE SUGAR INDUSTRY

THE PETROLEUM INDUSTRY

THE COAL INDUSTRY

THE IRON AND STEEL INDUSTRY

THE COPPER INDUSTRY

THE ZINC INDUSTRY

PAGE

THE POWER INDUSTRY

THE SHIPBUILDING AND SHIPPING INDUSTRIES

THE RAILROAD INDUSTRY

THE AUTOMOBILE INDUSTRY

THE AERONAUTICAL INDUSTRY

The Development
of
American Industries

1

Labor's Contribution to American Industries

Labor has made an essential contribution to American life, not only in carrying on the industries of our country, but equally in shaping the ideals that guide millions in their daily lives. Our nation owes a debt of appreciation to American labor because its power has been used for constructive policies. Wage earners in the United States have, first of all, been citizens devoted to the ideals and practices of democracy; as wage earners, they have sought to square their economic policies and practices with these ideals of democracy.

Within three-and-a-half centuries, the United States, which represents one twentieth of the world's total land area, was converted from primeval forests into the world's richest industrial country. The first-hand struggle with the forces of nature stimulated individualism, combativeness, and necessary acquisitiveness. The home of each settler was largely self-sufficient; the wife supplied the personal needs of the family, and the father was responsible for earning the money income and supplying the tools with which to earn it. In pioneer communities, there were few journeymen craftsmen, and those there were readily exchanged their craft for self-employment or a farm homestead. With the coming of mechanical power to drive larger-than-hand tools, industries left the home for factories, where people were paid wages for the day's work. But factory workers could always return to their homesteads in time of unemployment or could secure homesteads with little or no outlay of capital. It was not until the end of the nineteenth century that the opportunity for a free homestead for the taking was closed in the United States as a whole, although all such opportunities had long since passed in the New England and Middle Atlantic States. The passing of this frontier marked a new era in our economic life.

With the coming of industrialism, wage earners found that they had to work out their problems of progress as wage earners, so they early learned to supplement their individual efforts by uniting with their fellow workers to bring greater powers to bear on their economic problems.

In the early days, labor unions were local in organization and activity. Union organization on a national scale came with the development of national trends and organization in business.

As producing workers, sharing in the development of industries to supply the growing needs of the nation, wage earners, consciously or unconsciously, were one of the powerful factors in developing the principles that direct the management of industries. Organized workers have helped to create an informed public opinion that has influenced industrial and Governmental policies. Most of all, they have been effective in directing and controlling their own destinies. Organized in unions, they have given wage earners the tradition and practices of individual initiative through organized collective endeavor and mutual advancement.

Organized labor has given to industry workers who have the benefit of a public-school education and who have participated equally in all the rights of citizens of our republic. It has been an effective force in realizing democratic ideals in the daily lives of that great majority of our citizens—wage earners and their dependents. In order to level that barrier which creates the most permanent divisions between groups of citizens, the early labor movement sought to provide equal educational opportunities for all by establishing our public-school policy.

Since wage earners, before the establishment of our public-school system, could not afford to send their children to pay schools, they sent them to free schools, to which a stigma of charity was attached. The public-school system is based on the principle that the state is responsible for the education of its citizens and should provide all children with equal opportunities for an education. Historians agree in attributing to American trade unions the major credit for establishing our tax-supported public-school system.

Closely associated with democratization of education was the extension of the ballot to all male citizens, abolishing its restriction to those owning property. After wage earners gained the right to participate in the decision of political issues at the polls, they helped to extend suffrage to women.

Industry owes the labor movement a fundamental advantage, which it accepted without realization of its value and cost, namely, educated American wage earners with political status and hence definite resources for personal advancement. Certain practices and principles that have grown into industrial organization and management are outlined in the following sections.

Labor philosophy. Frontier life, which did not provide artificial conditions enabling the less rugged to live on the labor of others, tended to eliminate class distinctions and to provide opportunities for the real producers. The American labor movement caught this spirit of democracy and learned to look upon itself as a national institution, promoting the welfare of wage earners as an element in industry and society, seeking to make progress with others and not against them.

Because it accepted private ownership and the present organization of business as a system evolved out of economic needs and conditions that had defects but that could be made to function more equitably, the American labor movement set itself to get higher wages and shorter hours for

the workers. Wage earners accepted individual initiative as essential to progress and provided the means by which individual wage earners could coöperate with mutual benefit.

The American labor movement has consistently rejected all proposals departing from these fundamentals: individual effort and responsibility; voluntary associations for undertakings involving associated activity; insistence upon distinguishing between economic and political problems, and refusal to use political agencies to deal with economic problems; acceptance of the principle of mutuality—but not identity—of interests for all who are engaged in production but who have conflicting interests in division of gains; acceptance of the idea of interdependence of interests as the outstanding factor in the relationships between enterprises in the same industry, between industries, and between nations operating in regional or world markets.

The American labor movement made its first major objectives shorter hours and higher wages because determination of these two conditions controls opportunities for higher standards of living and wider activities and interests. It has been practical and realistic, refusing to be misled by theoretical plans to reorganize business or society.

Any system must be operated by human beings. The only way to get a lasting reform is through education of the persons who operate the system to a better understanding of forces and to higher objectives. Out of processes of meeting daily problems should come progress and constructive changes. The American labor movement, in refusing to outline any ideal plan for human relations, has been influenced by an evolutionary concept of social order, believing that, in the last analysis, all progress rests upon an educational basis.

Trade unions hold that the work agreement should be a bona fide contract, jointly negotiated and mutually satisfactory. Labor believes that fact-finding and fact-using are essential to equitable determination of this work contract, although they have often had to resort to force to get a hearing for their contentions. An important objective has always been to keep permanently open the machinery for orderly adjustments of misunderstandings and new problems.

The principles and practices of associated activity. When manufacturing industries moved out of homes and small shops into factories, ownership of tools passed to employers. There were no standards of work relationship except those of master and servant, the former employing the latter to do work for him under his direction and upon his terms. The employer held that he was fully justified in disposing of his property as he saw fit, and all suggestions from the employed were regarded as interference with the employer's rights and prerogatives, which were considered absolute.

Wage earners, realizing they were not servants but essential contributors to a production enterprise, learned that, by uniting and acting as a group, they could make a forceful demonstration of the value of their services and thereby secure more equitable terms of work. Their very act of organization was once held to be a conspiracy against the employ-

TABLE I

WORKING STANDARDS FOR ALL INDUSTRIES

Year	Hourly Wages		Hours	
	All industries	Union industries	All industries	Union industries
1890	$.21	$ .34	58.4	—
1900	.23	.36	57 3	—
1910	.29	.48	54.6	49.5
1920	.69	.99	50.4	45.9
1926	.71	1.22	49.8	45.4
1930	—	—	—	43.9

TABLE II

WORKING STANDARDS FOR MANUFACTURING INDUSTRIES[1]

Year	Hourly Wages		Hours	
	All manufacturing industries	All union manufacturing industries	All manufacturing industries	All union manufacturing industries
1890	$.20	$ .32	60.0	54 4
1900	.22	.34	59.0	53.0
1910	.26	.40	56.6	50.1
1920	.66	.88	51.0	45.7
1926	.65	1.01	50.3	45.9
1929–1930	—	—	50.1	—
1941 (May)[a]	.726	—	40.8[b]	—

[a] United States Department of Labor, Bulletin 12101, released July 16, 1941.
[b] Wage and hour law in effect

tions for large-scale production, progress of union organization was checked in the twentieth century, until the Federal Government, during the First World War, underwrote the right of workers to organize. With the development of management techniques and principles that had grown out of large-scale production, management developed labor policies and methods for dealing with workers, which it called "employee-representation plans" but which the workers called "company unions." This development was in essence a subtle method of opposing union organization without resort to force and violence. Company unionism grew extensively during the period of peak industrial prosperity that ended with the stock-market crash in 1929. As the great depression settled down upon our economic institutions, unemployment and want stalked the land. Hope of relief came with the National Recovery Act, which brought new freedom for wage earners to organize. As collective action by employers, under this act, was exempt from proceedings under anti-trust law, so section 7(a) of the act assured workers of the right:

[1] American Federation of Labor estimate.

> to organize and bargain collectively through representatives of their own choosing, and shall be free from the interference, restraint or coercion of employers of labor, or their agents, in the designation of such representatives or in self-organization or in other concerted activities for the purpose of collective bargaining or other mutual aid or protection.

The result was a great uprising of wage earners to join the unions of their trades or callings. When the act was nullified by the Supreme Court, the Administration and Congress realized that this new right and freedom could not wisely be denied labor. The National Labor Relations Act was enacted to guarantee wage earners the right to union membership for purposes of collective bargaining. Interference by employers with this right was made an unfair labor practice, prohibited by law. Society's assuring to workers this right to organize has provided millions with an opportunity to bargain collectively with their employers, so that work can be performed under contractual conditions mutually satisfactory to both parties. In addition to assuring a basic right to a large group of citizens, there begins the formulation of ethical standards in a new field.

Difficulties in emerging from the economic cataclysm that paralyzed business from 1929 to 1933 helped to make clear basic changes that had taken place within our population and our economy. The center of population had moved westward. Ability to transmit electric power had removed many of the conditions that restricted the location of industries. Transportation had improved and improvements in communication had practically eliminated distance as a factor in business relations. Figures from the Census of Population show that that proportion of the labor force which is engaged in agriculture had declined from 53 per cent of the total labor force in 1870 to 21.4 per cent in 1930. Our birth rate had declined, but our life span had lengthened, so that by 1939, 43 per cent of our total population was available for gainful occupation, as contrasted with only 32 per cent in 1870. In 1870, the proportion of the population depending upon manufacturing industries for a livelihood was increasing and continued to increase until 1920, but it has since declined. The output per worker has steadily increased, while the labor cost per unit of output has declined. The measurement of increases in man-hour productivity between 1900 and 1929 shows an increase of 125 per cent, with the sharpest rise between 1920 and 1929. Between 1929 and 1935, employment in manufacturing industries declined 31 per cent, while productivity per man-hour increased 27.2 per cent and output declined 13 per cent. While technical progress was steadily improving the machinery and processes of production, industrial research was finding new uses for old materials, new materials, and the chemical processes for creating substitute materials. In mining, transportation, public utilities, trade and service establishments, nearly 3,000,000 jobs were wiped out between 1929 and 1939, while the number of persons seeking employment steadily increased.[2]

---

[2] See Mills, Frederick C., "Employment Opportunities in Manufacturing Industries in the United States" in *National Bureau of Economic Research Bulletin No. 70* (September 25, 1938), and other studies.

All these changes in industry had their consequences for those human beings dependent upon industry for an opportunity to earn a living.

In this age characterized by collective action, various groups, including labor, have had to find and use the most effective procedures in dealing with public and private agencies. As society has assumed responsibilities and delegated them to be administered by Government agencies, the union, still the representative upon which labor depends, has found it necessary to study the methods of administrative law in order to find how best to protect the rights and welfare of wage earners.

Ideals of craftsmanship. In the early years of factory production, hand crafts were still essential to industry. Manipulative skill represented an investment on the part of the worker that had value to the employer. The union was the agency that maintained standards of craftsmanship and controlled the training of apprentices and their advancement to the rank of journeyman worker.

The training of apprentices was a responsible service to the industry and an essential factor in the development of the worker. With the coming of power-driven machinery, especially electric-power machinery, skills formerly supplied by hand were transferred to the machine. Training men for the new jobs involving the use of power machines became urgent for organized labor. Labor leaders saw that standards of workmanship, creative ability, and production conditions might be threatened if training were controlled solely for the purpose of increasing financial profits over a short-range program.

Fearing the chaos that would result from complete undermining of craft standards, unions looked for a broader basis for vocational training. They saw in the public-school system a social medium for meeting the broadening problems of vocational training. The American Federation of Labor advocated and helped in the final enactment of the Smith-Hughes Act, which authorized the Federal Board for Vocational Education. Under that act, the unions are coöperating in the training of workers for modern industry.

Increasing repetitive processes, with standardization of parts for mass production and mechanization of industry, have made obsolete old types of craftsmanship. Processes that formerly required manipulative skill are now done by machines at a much faster rate. In a sense, the older craftsmen were the pattern makers for the machines to which technicians have been able to transfer the work. Machine production has not destroyed the need for craftsmanship but has made necessary the development of new kinds of skills and new principles of vocational training. The union again is emphasizing the fact that workers have minds and wills as well as muscles.

However much machinery may be perfected, there is always need for the human hand and judgment. To fit the worker to use both effectively remains the function of vocational training.

The union serves as a repository of work experience, as the clearing center for workers' vocational problems, and as an administrative agency competent to formulate and carry out policies.

Wages and hours. As tides of immigration brought skilled craftsmen from the industrial countries of Europe to our ports, established wage earners taught them American customs and standards of living. The newly arrived immigrants brought with them familiarity with the technique of unionism, and the result of their association with American workers was the beginning of an American trade-union movement, adapted to American problems and conditions. This movement was retarded by the Civil War and the business depression following, but was well under way again in the seventies. Printers, cigarmakers, iron- and steelworkers, carpenters, molders, shoemakers, and so forth organized trade unions for the purpose of helping the workers to share in American prosperity. They first concentrated on two fundamental objectives: higher wages and more suitable standards for work hours.

Wages and hours in factories were carried over from home industry and agricultural standards. Unions began their long and difficult task of showing industry that wages and working conditions have to be adapted to industry and adjusted as industry changes. First the unions set 10 hours as the length of the workday, then 8 hours for those advanced groups that achieved the first goal. Then they urged the need of rest at the week end—1 day in 7; then they tried for a little leisure—a Saturday half-holiday; then the 5-day week.

In this movement for the shorter workday, the unions were conserving the health and labor power of the nation—a national asset indispensable to sustained industrial progress. Labor's struggle for the shorter workday, which has often forced them into the dogged resistance of strikes, has been slowly establishing the principle that economies of time are necessarily a part of industrial planning and management just as definitely as are economies of materials, capital, management, and so forth. The development of the techniques of time economies involves adjustments, balances, fitness. An antiquated workday standard in a shop equipped with high-powered machine tools is just as inappropriate as are Franklin heaters in a modern apartment building.

First and most important of the serious social and economic problems that have grown out of the introduction of machinery and power is the problem of machine displacement. Persons who have served years of apprenticeship and additional years as skilled, trained workers have found their skill and training rendered valueless and ineffective. Furthermore, through increased productivity as a result of improved machinery, many have been forced into unemployment and have been obliged to seek opportunities for service in newer industries, where their acquired skill and training is of little or no value. Actors, musicians, artists, telegraph operators, in addition to other skilled workers, have been displaced through the introduction of machinery. For instance, a power-operated machine used in the manufacture of men's clothing, operated by not more than 2 persons, displaces 200 skilled clothing cutters. Thousands of musicians have been displaced through the introduction of movietone and mechanical music. Human displacement of this kind and character is going on constantly. Gradually, through the years,

machines have taken over work that used to be done by hand, so that, if we compare present methods with those of a century and a half ago, we see astonishing changes. For instance, one girl with modern spinning machinery in a textile mill, by working an 8-hour day, can turn out as much yarn as an army of 45,000 with spinning wheels 150 years ago. Similar changes have occurred in other industries over this long period of time.

The amazing thing is that changes affecting thousands of workers have taken place almost overnight and without any plan for the future of displaced workers. In some industries, machines have been introduced so rapidly that, in a few years time, changes have occurred comparable to a century of earlier progress. This fact has been strikingly illustrated in the manufacture of electric-light bulbs. In 1918, it took 1 man a whole day to make 40 electric-light bulbs. The next year came a machine that made 73,000 bulbs in 24 hours. Each of these machines threw 992 men out of work. Similarly, in the boot and shoe industry, 100 machines take the place of 25,000 men. In the manufacture of razor blades, 1 man, in 1931, could turn out 32,000 blades in the same time needed for 500 in 1913. In automobile factories, similar changes have taken place. In 1930, in a Middle Western state, a huge machine could turn out completed automobile frames almost untouched by the human hand; about 200 men are needed to supervise this vast machine, and they produce between 7,000 and 9,000 frames a day. Compare this with a well-known automobile plant in Central Europe where, in the same year, the same number of men were making automobile frames by older methods; they turned out 35 frames a day.

There are other outstanding examples of the effects of technical progress, for example, 20 years ago all cigars were made by hand; by 1929, 35 per cent were made by machines operated by girls, and by 1933, fully 50 per cent were machine-made.

In 1929, 250 men on a line finished 100 eight-cylinder motor blocks; in 1935, 19 men achieved the same output.

Between 1919 and 1925, an average telephone operator increased by 25 per cent the calls she completed per hour; in 1935, the number completed in an hour increased 35 per cent.

In the steel industry between 1929 and 1939, 53 old-process mills producing plate, tin plate, and sheet were permanently abandoned and replaced by the continuous-strip process. This change has displaced 38,470 workers. In addition, in large integrated mills that are planning to install the continuous-strip process, 22,950 workers will be displaced if and when the new process comes into operation. The strip process in these large companies put a number of small companies out of business, throwing out an additional 23,350 workers. The total of those already displaced and those who will be displaced if present plans become effective is 84,770.

Industrial rayon developed a continuous-spinning process that cut time in one phase from 85 hours to 5.5 minutes.

The cotton-picking machine, which is expected to come into operation

within 5 to 10 years, will probably dispense with the labor of 500,000 hand pickers.

Highly perfected machines for making cigarettes, shoes, glass bottles, glass dishes, textile fabrics, tractors, electric cranes, and shovels have greatly reduced the time necessary to meet the needs of our markets.

The problem of technological unemployment has become increasingly grave. New industries do not develop rapidly enough to absorb the army of those looking for jobs. Technological progress has resulted in the bitter human tragedy of no job and no income, hunger and personal deterioration. It is absurd to accept the defeatist idea that human intelligence can devise technical improvements but is unable to find a way to make these improvements serve as labor-saving devices for the advancement of human welfare. Saving labor should increase leisure and not unemployment. We can reach this objective by planning to this end.

During the business depression and banking collapse following the stock-market crash of 1929, we came to a new understanding of social and private responsibility for maintaining jobs for those dependent upon daily work for income. We recognized that new considerations were involved in fixing hours and wages for workers in an age of power production. We realized that there must be a sustaining relation between consumer incomes and the output of industries.

Industries cannot exist without buyers. It is extremely significant that 93 per cent of all families in the United States have annual incomes under $3,000 and that three quarters of these incomes are under $1,500. Most of these incomes, of course, are spent for necessaries, so that no further explanation is needed as to the most direct way to increase purchases of consumer goods. Increased activity in consumer-goods industries leads directly to greater production in capital- and permanent-goods industries. When we start such a chain of cumulative forces, unless we make sure that an adequate share of returns from production is allocated to wage earners to maintain consumer power, we are planning, not for lasting recovery, but for a continuation of ups and downs in production and employment. In addition to including adequate wages in our plan for sustained progress, we must include a standard for workday and work week which assures employment for those that need it. With modern production and increased productivity per worker, there need be no fear that wage earners will not produce enough in return for a good living wage. Sustained production will extend this wage throughout the year. Industries that cannot stabilize should take this factor into consideration in fixing rates. These facts and principles the American Federation of Labor reduced to its formula: the 30-hour week, with *no reduction in earnings.* We urged unions to secure the 30-hour week by union agreement and, through petition to Congress, to make 30 hours the standard by Federal law. Our insistence seemed to assure the passage of this law, but upon the request of the Administration, we put our plan in reserve to facilitate the enactment of the National Recovery Act, described above.

High-wage principle. Years ago, industry accepted without question the idea that low wages were an asset to any industrial undertaking. A management that succeeded in reducing wages to the lowest possible rates was considered efficient, because low wage rates were assumed to be low labor costs. Wages, in the earliest factories, seem fantastically low. The average hourly rate in 1840 was 10.1 cents, which increased to 72.7 cents by the end of 1939. Price declines also steadily raised real wages, as represented in the buying power of wages.

Organization of workers into trade unions put system into wage earners' business arrangements. By organizing for control of the labor market, workers were able to insist upon higher wages. Steadily we built up and proved the principle that better hours and wages make for more efficient workers. We formulated the theory that workers with initiative, experience, and physical vigor are more valuable in the industry employing them.

Labor first pointed out that wages represent customer buying power in business depressions. Employers had assumed that the best way to meet depression was to curtail rigidly all expenditures. The first step was usually to cut wages. In 1896, labor pointed out that wage cuts only deepened the gloom. Because factory orders declined, customer buying was reduced in the retail market. In 1912, labor said: "No industry—no country—has ever become great or ever can become great founded upon the poverty of its workers." In each succeeding depression, labor warned against the consequences of wage cuts and announced that it would fight wage cuts. All workers—organized and unorganized—recognized the validity of this principle and accepted it as the basis for their action.

In 1919, the American Federation of Labor first adopted a formal declaration recognizing increased productivity as the way to progress:

> The increased productivity of industry resulting from scientific research is a most potent factor in the ever-increasing struggle of the workers to raise their standards of living, and the importance of this factor must steadily increase since there is a limit beyond which the average standard of living of the whole population cannot progress by the usual methods of readjustment, which limit can only be raised by research and the utilization of the results of research in industry.

In 1921, the Federation declared:

> There are but two avenues leading to permanent, higher standards of living for our people as a whole. One of these is the elimination of waste, either in the form of mismanagement or of undue exploitation and profiteering. The other is increased productivity. Both must be traveled simultaneously.

This statement was rounded out by the 1925 convention, which formulated labor's wage principle as follows:

> We hold that the best interests of wage earners, as well as the whole social group, are served by increasing production in quality as well as quantity and by high wage standards, which assure sustained purchasing power to the workers and, therefore, higher national standards for the

> environment in which they live, and the means to enjoy cultural opportunities. We declare that wage reductions produce industrial and social unrest and that low wages are not conducive to low production costs.
>
> We urge upon wage earners everywhere that we oppose all wage reductions and that we urge upon the management the elimination of wastes in production in order that selling prices may be lower and wages higher. To this end we recommend coöperation in study of waste in production, which the assay of the Federated American Engineering Societies covering important industries has shown to be 50 per cent attributable to management and only 25 per cent attributable to labor, with 25 per cent attributable to other sources, principally managements in industries producing commodities for any single industry under consideration.

As this declaration points out, distribution policies must mesh in with mass production, which undertakes to supply products for the masses—that is, the wage earners. So labor pointed out a basic principle in industrial balance, namely, that wages are something more than payments to producing workers for services; they constitute consumer credit upon which retail trade depends.

In the past 20 years, Dr. Spurgeon Bell[3] finds the following significant changes for industrial workers:

(1) Hourly earnings in money terms increased 20 per cent.
(2) Hourly earnings in purchasing terms increased 45 per cent.
(3) Weekly earnings in money terms declined 10.1 per cent.
(4) Weekly earnings in purchasing terms increased 10 per cent.
(5) Between 1923 to 1925 and 1935, the rate of productivity per man-hour increased 44 per cent, whereas unit costs of product decreased 17 per cent.
(6) The volume of production did not increase in proportion to increasing productivity.
(7) The volume of employment materially declined.
(8) Annual wage incomes declined materially; in money terms they declined 30 per cent, in terms of purchasing power 20 per cent.
(9) Working hours per week declined from 49 to 39.

In addition to these disturbing trends, indicating decreasing production and unemployment, the record of unemployment mounted to over 15,000,000 in 1933, falling to 7,000,000 in 1935, and up again to 10,000,000 in 1940. These figures do not include the unemployables.

Obviously, our most urgent problem is to increase production and national income, and thereby to increase employment and annual incomes of wage earners. Labor maintains that the solution of this problem rests primarily with private industry and the bankers, and has repeatedly pledged its willingness to coöperate.

Functions and responsibilities of organized labor. In earlier days, unions were mainly fighting organizations with a responsibility for apprentice training, in order to maintain standards of craftsmanship. They assumed no responsibility for management or for assisting with

[3] Bell, Spurgeon, *Productivity Wages and National Income* (Washington, D. C.: The Brookings Institution, 1940).

the problems of management. Nor was there a distinction between ownership and management in these early days. But later concentration of financial control, the corporation method of financing, subdivision of processes, and standardization of parts and machines very definitely defined management as a separate function. It developed simultaneously with efforts toward more scientific management of the materials of *production.*

The management movement was led by a few able, farsighted thinkers, but it attracted to it many who did not understand or appreciate the aims of its founders. Some of these who came into this new and growing profession had no understanding of its social implications or the purposes and ideals of the labor movement. They irritated workers by turning them into subjects for experimentation. They ignored the experience and intelligence of the workers, and thus created a deep sense of personal injury. Wage earners everywhere protested against so-called "scientific" management. Both labor and those in the management movement who really understood the principles of management pointed out that no method could be truly scientific which deliberately excluded a source of primary information and ignored the fact that work plans had to be executed by workers whose will to coöperate represented a distinct production asset.

Wage earners, through their unions, have pointed out that producing workers who handle materials and tools have a special knowledge of work problems that no one else could have and that this knowledge is essential to balanced scientific planning. The extent to which a worker's work should be planned for him depends upon the particular task involved, its surrounding conditions, and the ability of the worker. In a very real sense, a certain amount of planning must be done by those on the job. There must be coördination of all experiences and interests to eliminate personal bias.

The protests of labor were effective in pointing to defects in the application of scientific management and in helping management to find more comprehensive principles. The controversy focused attention on the human element and on coöperation as the method for getting the best results through associated activity. Consent of worker and management is indispensable for coöperation.

Some unions have seen the possibilities of offering coöperation to management in reducing wastes and in working out production economies. Where management is farsighted enough to accept the offer, such undertakings are called "union-management coöperation." They represent progress in organizing the relationships set up by collective agreements. They apply to the problems of daily work the method by which the work contract is negotiated, and give workers an opportunity to use their experience and intelligence in a wider way and to participate as an organized group in directing the destinies of the industry.

The possibilities of this sort of mobilization of the brain power of the full producing staff exist wherever collective bargaining has been set up. Without definite plan, coöperative undertakings have developed in many

places. Among the definitely organized, the best-known union-management undertakings are the coöperative relations between the railway shop-craft unions and the Baltimore and Ohio and the Canadian National Railways.

In the shops of these railroads, joint committees are set up consisting of equal representatives of management and workers. These committees have made thousands of suggestions that resulted in economies and more efficient work. Working conditions have, consequently, materially improved, and shops where the coöperative program is in effect are recognized by their safer, cleaner, more sanitary, and more comfortable conditions. The coöperative policy has been instrumental in reducing the costs of production and sales. Agreement as to what shall constitute a normal force, the more scientific budgeting of maintenance expenses, the establishment of placement bureaus, economies in reconditioning and building of cars and locomotives, and so forth have grown out of coöperative efforts and have contributed materially to the greater stabilization of employment in railroad shops and hence to the stabilization of incomes.

The International Printing Pressmen's and Assistants' Union maintains a newspaper engineering service responsible for maintaining high standards of efficiency and workmanship in the production methods and products of those firms with which its unions have contracts. This service sends a monthly letter to each firm reviewing the work done in their plants, pointing out defects and suggesting remedies. Experts are sent to overcome difficulties, to give advice on the construction of buildings to house pressrooms, and to supervise installation or overhauling of equipment. These services to employers supplement the sustained efforts of the International to maintain higher standards of craftsmanship.

The practice of coöperation discloses the fact of labor's real partnership in production. By its insistence on rights and justice, the organized labor movement has been leading to a better understanding of the relationship between producing workers and the institution to which they are attached. These workers have a real investment in their jobs. They invest their time, their energy, their creative capacity, and they organize their lives to suit their jobs. They carry on the work processes necessary to send to markets the products that bring financial returns to the industry and maintain the standards of products upon which the firm's good will rests. Not only do workers feel a pride of possession in their jobs, but they depend upon them for incomes to pay the costs of living.

As partners in production, workers have a right to security of relationship. Every work contract should have a time clause, specifying the time for which the worker is employed. Such guarantees would necessitate a carefully planned budget, making emergency provision for workers as well as for capital and materials. The organized labor movement is working for job security, which, it maintains, is necessary to industrial stability.

National social program. The economic cataclysm made conspicuous the absence of any social program. To meet the emergencies of our citizens, the Social Security Act, approved in 1935, provided for Federal

contributions on a matching basis to states for old-age insurance for the needy; Federal old-age insurance on a contributory basis for self-supporting persons; a Federal tax for unemployment compensation, with provisions for offsetting state taxes paid for the same purpose; and Federal grants for state provisions for dependent children and mothers, physically handicapped children, and for the blind. Intelligent thought for the future welfare of the nation requires that we provide for dependent children who are the future citizens. Our lack of experience in social insurance is retarding our efforts to develop real social security quickly and effectively. One of the main difficulties was failure at the start to realize that a national security program must rest on a Federal law prescribing minimum standards that would establish a basis for fair competition for industries operating in national markets. Future progress must correct this basic difficulty and make benefits adequate.

Following the nullification of the National Recovery Act, the Fair Labor Standards Act was enacted, fixing, for industries under Federal jurisdiction, minimum standards for wages and hours—fixing a floor for business competition. The Public Contracts Act gives similar protection to workers employed on work covered by Government contracts. This legislation supplements other laws that set up regulations and controls over private business in order to promote social interests and welfare.

The National Labor Relations Act, supplemented by similar legislation in the important industrial states, represents a new charter of liberty for wage earners and small-salaried workers, giving them a new status. With the right to collective bargaining assured comes real opportunity to advance labor's interests, with responsibility for making all efforts constructive. Whatever terms of employment are agreed upon by employers and workers' representatives, those terms should be put in writing, so that there can be no mistake as to meaning or conditions. This contract is then available for continuous reference during its life.

During the past decade, workers have had greatly increased experience with factual presentations of cases—under the NRA, under the National Labor Relations Board, under Fair Labor Standards, Public Contracts, and so forth, as well as in collective bargaining. Faced with the demand for facts to prove their cases, workers have increased the need for research and technical assistance. They turn from force to facts wherever possible. They look forward to the time when the accounts and records of the employing firm will be the basis for collective bargaining in order to determine what portion from sale of products they helped produce should go to producing workers.

Congress of Industrial Organization. In 1935 a few international unions impatient with the process of discussion and majority decision organized a committee to promote industrial unionism. Subsequently the committee developed other than educational functions and the internationals composing it were suspended by the executive council of the American Federation of Labor for forming a dual organization. Repeated efforts have been made to compose the differences between this group and the American Federation of Labor. The Federation has

consistently advocated a basis of organization suited to the need of the workers concerned. The Federation chartered the first industrial union, the United Mine Workers, and also chartered craft unions. Changes in industrial conditions and the wishes of union members should determine whether a union should follow strictly craft lines or take in all employed in an industry, and their wishes must take into consideration the rights of existing unions in a particular field for which the union is assuming responsibility. The fundamental policy of the Federation is voluntarism but voluntarism we know can exist only when we recognize and accept attendant responsibilities. The American Federation of Labor assures to its affiliates self government and expects from them full performance of duty in the light of the welfare of all.

Labor's objectives. The organized labor movement represents one of the strongest spiritual forces operative in our nation. It is a force that expresses the desire of men and women for personal advancement and progress, and, developed with a sense of responsibility, it becomes a great lifting power for human welfare. We do not live by bread alone, but bread is the staff of life. We do not seek shorter hours and higher wages for these ends in themselves but because we want a fuller and more abundant life for all.

We want our families to have better and more comfortable homes, making family life happier; we want adequate food, clothing, and medical care, and education for our children; we want to make our contributions to the social organizations and churches of our choice; we want to accumulate savings against the human emergencies that overtake us all. These are not extravagant objectives but are the legitimate desires of a free people.

We believe there is intrinsic value in every human being, which gives him the right to choice in matters affecting his life. Organization into unions serves to secure this right for the wage earner and develops agencies within the union to help the worker exercise his precious right effectively. Despite legislation and other aids developed for the worker, the union remains the basic agency for promoting the welfare of wage earners in former and new fields A constructive labor movement is an asset of incalculable value to industry and to the nation.

2

The Agricultural Industry

Early History

Women the first farmers? Women probably were the first farmers. For many centuries, man clung to hunting and herding. Woman developed agriculture near the camp or cave. Most economic advances in early society were made by women. From the cotton plant, which the Greeks knew as "the wool-bearing tree," primitive woman rolled thread and made cloth.

Botanical and zoölogical evidence indicates that man's first agricultural economy probably developed in the Near East, which includes Syria and Iraq. This area is the only place where the wild plants and animals that became the basis for an agricultural economy existed.

Records preserved on ancient monuments contain the gist of Egyptian agricultural history dating back to 3000 to 4000 B. C. Various animals had been domesticated. Crops were grown for man and beast under a system of tillage and irrigation, which was united with the feeding of large numbers of animals on the ranges. Agriculture in Babylonia supported a dense population. In Persia, industry was poorly developed, but agriculture was exalted as the basic and noblest occupation of mankind, and the common man devoted himself completely to the culture of the soil. Scripture abounds in allusions to husbandry in Palestine and Egypt.

Britons taught by Romans. Greek literature, from 1000 B. C. to the conquest of Greece by Rome in 146 B. C., throws considerable light on agriculture in that period. Into the "backward" countries which they conquered, the Romans carried their agriculture. To the Britons, the Romans taught agriculture so effectively that, before the occupation ended, they were exporting large quantities of grain.

Indian agriculture in North America. More agricultural progress had been made prior to the coming of the white man to North America than is commonly supposed. Most of the Indians east of the Western Plains lived in settled villages and cultivated the soil. Indian corn was their chief food. A million bushels of ear corn were raised annually. "When the women plant maize," said their crafty men, "the stalks pro-

duce two or three ears. Why? Because women know how to plant corn to ensure its germinating. They know more than we do."

When the whites made their first settlements in North America, a tribal family of American aborigines lived in the region between the Hudson River on the east and Lake Erie on the west. To the French, these Indians were the Iroquois; to the English, the Six Nations. They had achieved for themselves a higher degree of civilization than any other race of aborigines in the New World, except for some of the inhabitants of Peru and Mexico.

The Iroquois practiced a crude agriculture, but it was superior to that of any of their savage neighbors. They fashioned earthen pots, wove baskets and mats, spun twine, made canoes, cured skins, smoked stone pipes, and contrived beads and wampum. For untold generations their agriculture had been carried on in all of the forests of New York, as in all of the forests, plains, and deserts of the continent. Agriculture, however, could never advance far without beasts of burden. The Iroquois and other Eastern Indians had none; but Indians of the Plains, at the time the Atlantic Seaboard was settled, had herds of horses, which roamed into Texas and California.

Plants and trees that the Iroquois used for food and other purposes numbered about 75 species. Remnants of Indian agriculture are still to be found as practiced three centuries ago in the six Indian reservations, where live 5,500 descendants of the Six Nations. Domesticated plants, numbering 553 species, are under cultivation in various parts of the world; and about 4,450 species some part or parts of which are edible are grown. Of the cultivated species, 448 are of Old World and 115 of New World origin.

From barbarism to civilization. Before agriculture, the earth could have supplied no more than 20,000,000 men. Now the world's population is 2,000,000,000. Voltaire wanted to know the steps by which men passed from barbarism to civilization. Man began to be human when, through the uncertain hunt, he developed the greater security and continuity of pastoral life, which offered the advantages of domesticating animals, breeding cattle, and the use of milk. He may have begun to domesticate animals when the helpless young of slain beasts were spared as playthings for his children. Then, too, animal milk released women from prolonged nursing.

Agriculture the base of civilization. A high state of civilization is impossible unless it is based on agriculture. Where people wander all the time, they cannot accumulate the appliances that are essential even to the lowest real civilization. Agriculture is a peaceful occupation, the pursuit of which tends to breed out the physical strength of nomadism Instances in which nomads have ruled over tillers of the soil are those in which the tillers had declined in vitality and strength. Between these two groups the difference in their way and economy of living has always tended to produce mutual contempt and hatred. After the development of agriculture 30,000 to 40,000 years ago, it became possible for man to be sedentary and live largely on the vegetable kingdom.

In the New Stone Age (10000 B. C. in Asia and 5000 B. C. in Europe), men not only chipped their stone implements but also smoothed and polished them. Men in that age knew the rudiments of agriculture. New Stone Age rock carvings show a peasant guiding a plow drawn by oxen. This marks an epochal invention of history, for men of the New Stone Age had strengthened the foundation of civilization by domesticating and breeding animals. Old cities of the New Stone Age are variously dated from 12000 to 18000 B. C. Agriculture as a crude art made these cities possible.

Agriculture Becomes a Business

Farming as a mode of living. Farming in the United States was idealized and popularly accepted as a mode, or way, of living down to about 1900. Frugal farm families who worked hard on fair-to-good farm land made small net returns. An agricultural college dean, 40 years ago, said that "farming is the best of all vocations because nobody can get rich in it." Farm families have long drawn heavily on the intangible or psychic income that nature provides in the old trinity of form, color, and sound. Even in 1939, the head of the National Grange wrote that "farmers must learn to cash in on the scenery, beauty, health, and recreation of the farms and homes of our land."

Fifty years ago, farmers possessed arts and skills that have since largely been lost. Farm men and women were equipped for living by a high degree of literacy in their hands. Hired laborers on farms were called "hands." Families in every farming neighborhood assumed as a matter of course the care, in their own homes, of aged or indigent relatives. Rural people in general were warmly and actively human. Mutual aid among them was always forthcoming in crises and misfortunes.

Rural churches were well supported. From family Bibles, members drew inspiration, faith, fortitude, and human experience. Farm people felt akin to the rural people whose way of life in Bible lands was similar to their own. Burial grounds received respectful care. Most one-room district schools, to which 15 to 30 children walked 2 to 4 miles, had 6-month terms. School dinner pails or baskets carried by pupils contained substantial kinds and quantities of wholesome foods. Women teachers were the rule. Picnics, spelling bees, popcorn parties, games, and simple dances provided social recreation and entertainment.

Fairly stable land values. Land values were fairly stable at prices that discouraged speculation. Farms were mostly in the occupying ownership of second-, third-, or fourth-generation heirs of pioneering settlers. Sales of farms were few and far between. Almost every farmer, however, knew or believed that his land was worth more than he had paid for it, in cash, and that it was increasing rather than declining in cash value. Based on their experience, skills, habits, and economies, farm people had a sense of security on land. They owned their homes; they could produce their own living; they feared debt; they knew little

or nothing of other occupations; they lived in a local world that they believed would remain essentially as it was.

Bankers in their back offices made character loans at 8 per cent to farmers whom they knew, respected, and trusted. A few young farmers read law in county-seat towns, and became practicing attorneys and politicians who held public offices. Mortgaged farms tended to stigmatize the farmers who occupied them. Taxes were not burdensome. Farm families were large, compared with farm families in the same communities today. They seldom had much cash. At stores in rural towns —reached by dusty, muddy, or icy roads—they exchanged produce from their own supplies for dry goods, shoes, coffee, sugar, salt, and the like. In short, farmers were neither poor nor wealthy.

Couples married young. Most young people married at the customary ages of consent and engaged in farming in their neighborhood or in an adjoining county or in a Western state. They were likely to start with a few hundred dollars in cash, some livestock, poultry, seeds, household chattels, and complete confidence in their ability to make a living and increase their assets on a farm.

Drought periods in the United States. During the period between 1895 and 1930, there were a number of droughts of the transitory class—short-lived and often affecting seriously only comparatively small areas. Among these may be mentioned that of 1901, in the interior valley and the Southwest. The following year, 1902, had adequate moisture in most states. Another transitory drought occurred in 1910, principally in the Central and Northern states and in the South, but this again was largely a one-year affair. Another, in 1917, affected mostly the Southwest and Northern Plains, and still another, in 1925, was severe in the South and Southeast.

For some 60 years up to 1930, there were a number of short-period droughts, but only one persistent and markedly dry phase of United States climate, the 1886 to 1895 decade, lasting, in general, about 10 years; some years, of course, were better than others. The 1930 decade drought period also had several years with fairly favorable precipitation, but there were three disastrously dry years: 1930, 1934, and 1936.

Agriculture from 1785 to 1860. During the 75 years before the Civil War of 1860, more agricultural progress was made than in all previous history. America acquired and conquered a continent equal to that of Europe. Its population multiplied nearly eight times, from 4,000,000 to 31,500,000. Trails, roads, turnpikes, steamboats, canals, railroads, and the telegraph were developed. Agricultural societies were established from 1785 onward. In the field of agricultural literature, the first American journal appeared in 1819.

Agricultural teaching grew from a single chair in Columbia University in 1792, through a series of short-lived local schools beginning in 1823, to agricultural colleges, of which five developed between 1854 and 1860. It was in machinery, however, that the greatest advance was made. With the invention of the cotton gin in 1796, progress was rapid. Wooden plows and wooden harrows gave way to tools of iron by about 1825, and

then to tools of steel. In the first half of the century, the invention and use of the mower and then the reaper made it possible for fewer persons to harvest larger acreages, and the surplus labor thus created went to settle new areas.

In general, practically all of the progress and improvement in agriculture that has just been summarized was accomplished by farmers themselves, without official assistance. Many Government officials, however, gave much assistance in their capacity as private citizens.

Increased Mechanization of Agriculture

Dawn of a new age. In the eighteenth century, 75 to 95 per cent of the people in the United States were required to produce the nation's food and fiber supply. In agriculture, the machine age dawned about 1850. Earlier than that the appearance of machine power on farms was mentioned by the Commissioners of Patents. By 1862, steam power occupied much attention in reports of the first Commissioner of Agriculture. Agriculture's animal-power era was characterized by sharp decreases in the percentage of population needed on farms. Once the machine got under way, population shifts were greatly accelerated. First the modern plow came into use, and later the binder. Firearms and barbed wire made settlement of the Great Plains possible.

Agricultural colleges and experiment stations. In 1862, the Morrill Act made grants of public lands to establish land-grant colleges, which began to teach agriculture and the use of engineering and technology as applied to agricultural production. In 1887, the Hatch Experiment Station Act provided Federal aid for agricultural research in the United States. Animal power was in extensive use on farms in 1920, but its maximum was attained in 1910. Although mechanical power began to be used even before 1862, it exerted small economic influence until 1910, and that influence became drastic only after 1920.

The internal-combustion engine came into farm use as early as 1890 and electricity as early as 1900, but what may properly be called modern agricultural technology did not get under way until after 1920. Between 1919 and 1924, the nation's cropland decreased by 13,000,000 acres—the first decrease ever recorded. It was accompanied by large decreases in both the number of farm animals used for power and in the farm population. Yet, although decreased in numbers, farm workers produced 6 per cent more in the period from 1922 to 1926 than from 1917 to 1921, because production per worker increased 15 per cent. From 40 to 80 per cent of the cost of crop production is now attributed to power and labor.

In the wake of the machine. Dilemmas and troubles have grown out of the use of new machines, improved plants, advanced processes, and better animals. Modern technology complicates production, living conditions, distribution, trade, employment, and prices. Difficulties arise from unequal responses to changes and innovations. In 1934, about 30 per cent of all farmers did part-time work off their farms to supplement their income.

Horses and mules in the United States numbered 21,431,000 in 1915 and 10,616,000 in 1940. Mechanization has changed agriculture so swiftly and so surely that, between 1915 and 1940, the tractor, truck, and automobile eliminated the need for the labor of thousands of men. They also reduced horse and mule numbers by nearly one half in the last 25 years, thereby releasing probably 40,000,000 acres of cropland and as much more for pasture for meat and milk production. Consequently, vast regional shifts have occurred in crop and livestock production.

Solved problems create new ones. Science learns more about the needs of soils; engineers perfect labor-saving machinery; new ways to preserve food are discovered in the laboratories; plant innovations; ways to control insects and diseases; new uses for farm products; more knowledge of breeding practices and marketing—these and countless other developments bring higher productivity, better living for town and country people, improved nutrition and health, and the widening of markets But they also bring problems. No end is seen to these and similar results of science, genius, and accident.

Technical progress has provided many farm commodities. It has given farmers equipment that can increase each worker's output. Therefore, the machine may appear to be more important than the man. Forces have been set in motion that affect all people. Technology has initiated and is continuing a revolution in American agriculture.

Agricultural technology defined. Technology is science, art, and invention. It is tractors, combines, corn pickers. It is the testing and breeding of animals and the conquest of diseases. It is hybrid corn, new kinds of wheat, soybeans, kudzu, and lespedeza. It is ways to feed farm animals, plants, and men. It is road building and rural electrification. It is contour plowing, conservation of soil, management of forests, protection of wild life, irrigation, and flood control. It is marketing and distribution. It is a race between insect pests and ways to kill them Technology is in the workshop, laboratory, barn, grove, field, and home. It is a social and economic force that challenges thought and ability to plan. Its many-sided nature combines the intricate influences of getting and spending, savings and debts, employed leisure and unemployed relief.

Technology may be a paradox. Scientists discover that the crossbreeding of two highly developed strains of corn gives a productive and healthy hybrid. Within two short decades, hybrid seed corn is used on 24,000,000 acres; the estimated increase in yield in that time is 100,000,000 bushels. The force of change is still unspent. Not all the corn can be used. Prices drop; farmers worry.

The trend of technological changes. Looking forward from 1941, some of the technological developments mentioned seem reasonably certain to lead to the following primary changes:

A continued rapid increase in the adoption of tractors, especially the small general-purpose tractor with rubber tires; a further use of small combines, corn pickers, and other harvesting and tillage equipment operated by tractors; a rapid extension of rural electrification, especially if ... rt of the Rural Electrification Administration is continued, as in

1940; a slow but constant improvement in the productive efficiency of livestock and progress in the correction of nutritional deficiencies and disease control; a tendency toward considerable increases in corn production as a result of further adoption of hybrid seed; some increase in wheat and oats production as a result of wider adoption of new disease-resistant varieties; greater acreages of soybeans for seed production, resulting partly from better seed-yielding varieties, partly from improved methods of harvesting and from development of new industrial outlets; and the extension of flax and grain sorghums into new producing areas as a result of breeding cold-resistant and hardy varieties.

Shifts toward more efficiency. Technology will probably continue the shift from small-grain and tilled crops to forage and pasture in the interest of soil conservation; expand the shift from low-yielding to high-yielding hays; encourage the greater use of cover crops and other cultural and engineering conservation practices; lead to some increase in the production of corn and cotton as a result of greater use of cover crops in the South; expand the use of domestic wood pulp, and develop increased interest in forests and wood lots as sources of supplementary income for farmers; greatly increase the use of frozen packing of farm products; continue advances in the production of synthetic textile fibers; and widen outlets and uses of both edible and drying oils. It may develop starch production from sweet potatoes on a commercially important scale; and bring about some development of plastics and other industrial products from cellulose and protein, using mostly wood as the source of cellulose, and soybeans and casein as sources of protein.

John Rust said, in December, 1940, that the Rust cotton picker, which he and his brother invented, would be produced in 1941 on a large scale in a new plant. At the same time, he announced the development of a "highly efficient" cotton cleaner that can be used in conjunction with the mechanical picker.

Farming becomes a business. American agriculture in the present century has advanced far toward the status of a commercial business, employing science and machinery and the labor of more than 6,500,000 farmers and their families to produce a gross farm income of over $9,000,000,000 in 1937. The *Mid-Western Banker* (November, 1940) contained an article on "Making Business on the Farm and Ranch a Gilt-Edged Investment." *America's primary industry uses, not only many kinds of* machinery to save time and labor, but credit, fertilizers, genetically improved plants and animals, and efficient practices to increase output per unit of land.

Agriculture has achieved mass production of its principal commodities at decreased costs since 1900. Subsequent to the end of the First World War, which restricted foreign outlets for American farm-export products, the nation's agricultural industry has been depressed by recurring surpluses of major farm crops. Agriculture in the Western Hemisphere, particularly in the United States, not only is producing troublesome surpluses but possesses and is continuing to develop surplus capacity.

Preludes to Organizations of Farmers

Movements toward group action. A movement was started at the very beginning of the nation's existence to organize a national agricultural society under Federal auspices. This was recommended by Adams in 1776 and by Washington from 1789 onward. Out of a national convention of agriculturists held in the District of Columbia June 24-25, 1852, grew the United States Agricultural Society. It was a forerunner of later farm organizations as a pressure group. Marshall P. Wilder became its president, serving 6 years. Membership in the society comprised leading farmers. Fillmore, Pierce, and Buchanan appeared at its meetings; and, in 1862, it numbered Lincoln and all five living Ex-Presidents, as well as many Congressmen, among its members. Charles B. Calvert, a member, was elected to Congress July 4, 1861. He was placed on the House Committee on Agriculture, and worked persistently for the establishment of a Department of Agriculture. In 1859, an advisory board of agriculturists met at the behest of the House and requested the establishment of a Government department. On May 15, 1862, President Lincoln signed a bill bringing the United States Department of Agriculture into existence On February 9, 1889, the Department was raised to cabinet rank, and its supervising officer became the Secretary of Agriculture.

At grips with hard times. At a meeting, in 1822, of the Philadelphia Society for Promoting Agriculture, a member asked: "Why is it that Pennsylvania farmers have never yet found leisure to associate for the advancement of their own best interest?" In 1791, the New York Society for the Advancement of Agriculture, Arts, and Manufacture was formed; and in 1792, the Massachusetts Society for the Promotion of Agriculture was established. None of these societies seems to have seriously interested many practical farmers who farmed for a living. Addressing a session of the New Hampshire Board of Agriculture, in 1853, a speaker said that "the only reason why American farmers are without power is that they have never learned to act in concert."

American farmers were experiencing hard times in 1819 after the Napoleonic wars, and again in 1837; but their most serious, widespread trouble developed after the Civil War. They faced transportation and credit troubles, the rise of railroads, grasshopper plagues, rapidly increasing urban industry, and the disastrous end of a cattle boom when the Great Plains were overstocked and drought set in. Kentucky farmers were among the first in the United States to organize on a large scale to defend themselves against real or imagined enemy interests Tobacco prices in Kentucky had dropped from 10 to 6 cents a pound in 1878; sharp declines in land values occurred; and a wave of farm-mortgage foreclosures climaxed their grievances. They had no constructive plan or program of their own. Fair to good times tended to grow shorter between hard times. Feeling their way toward association with fellow farmers in a common distress, they were eager to join together.

Approximately 1,300 farm organizations at the time were local and social; they did not interest troubled farmers. Founded in 1867, the

National Grange grew slowly until 1873, when its membership began rapidly to increase. Solicited farmers were quick to join, hoping and believing that the organization could and would fight effectively and quickly to protect their interests. In 1875, the Grange had 850,000 members; but by 1889, the number had dropped to 106,782. Farmers had no experienced leadership within their own ranks to represent them in legislative bodies and elsewhere.

Other producers lag behind farmers. In August, 1892, Professor Charles S. Walker of the Massachusetts College of Agriculture read a paper before the American Economic Association in which he said:

> The farmers' industry has increased the supply of agricultural products beyond the demand, with the consequent fall of price. Here is revealed the efficient cause of his pecuniary condition. The trouble, however, is not that the supply is too great, but that the demand is too little. Other producers have not kept up with the tiller of the soil. . . . The farmers' movement is the awakening of these sturdy citizens from engrossment in manual labor to a sense of their duty, first to themselves and then to society. The movement may be slow, it may do much apparent damage, but it is irresistible, and though it may change the looks of things, in the end its results will prove beneficial.
>
> Organizations of farmers are strong in their field of action, in usefulness and in power. The movement is a widespread and powerful advance along all educational lines. Farmers are a unit in demanding the best education in everything pertaining to the science and art of agriculture, and to the knowledge and practice of manhood. The movement is progressive along the line of cooperation. In time, organized and educated farmers will master the difficulties of cooperation so far as it relates to agriculture. Organization, education and cooperation have led to political action within and without the old parties. From repeated failures farmers are learning how to take care of themselves politically They press and enforce their demands patiently and persistently, meeting all attacks bravely, believing that wherein their claims may not be for the general good the conflict with the demands of others will modify and correct them.

The Farmers' Alliance had started a movement in the 1870's which spread to the whole Midwest. In 1887, the Grand State Alliance of Texas joined with the Farmers' Union of Louisiana to form the National Farmers' Alliance and Cooperative Union of America. A year later, this organization amalgamated with the Agricultural Wheel of Arkansas, under the name of National Farmers' Alliance and Industrial Union. It sought to win over the labor element. By 1890, the organization had a membership of 2,000,000 farmers in 27 states; but the Alliance, as such, disintegrated. Its program, however, was carried forward by the Populist Party, which, at its convention in July, 1892, brought together and summarized the demands of organized agriculture.

Following the panic beginning in 1893, there was a surplus of goods that could not be sold at a profit at home.

A report on country life in 1908. President Theodore Roosevelt appointed a Country Life Commission in 1908. It held 30 hearings throughout the United States, and, directly or by correspondence, sought information and aid from over 100,000 persons. Dr. L. H. Bailey of New York

accepted the chairmanship of the Commission; the other members were "Uncle Henry" Wallace of Iowa, grandfather of Vice-President Henry A. Wallace; Dr. Kenyon L. Butterfield of Massachusetts; Walter H. Page, who became wartime Ambassador to Great Britain; and Gifford Pinchot, *subsequently Governor of Pennsylvania.*

A new leadership in rural affairs, the Commission reported, must be reared, not in town, but in the country. Most of the new leaders must be farmers who *not only can find a satisfying business career on the farm* but can throw themselves into the service of building up the community. Three principal recommendations by the Commission were: an inventory of rural resources, from the soil up; some way to unite all institutions, organizations, and individuals having any interest in rural life into one great campaign for rural progress; and the thorough organization and nationalization of extension work through the colleges of agriculture.

The philosophy of group action. Important decisions upon which action is taken are more and more those of bodies of men rather than of single individuals. By virtue of its organization, the modern nation is able, to some extent at least, to cope with social conflicts among individuals and groups within it.

Leadership in the farming business believes that organization is a necessary mechanism for use by farmers in their own interest. Business and labor strengthened their respective interests by organizing in advance of farmers. Organization by labor and nonfarm industry encouraged, if it did not constrain, farmers to organize, in order to keep pace with the march of technological progress and its world-wide implications. Farm leaders agree that organization on a state and national basis is necessary, not only in order to obtain Federal and state legislation in the interest of the agricultural industry, but also to oppose legislation which they regard as *detrimental or unfair to their industry.* Education and coöperation are repeatedly stressed as major purposes of the national farm organizations, and they have steadfastly encouraged the application of science and technology to the farming business.

Outstanding farm organizations. Corresponding to labor unions and associations of businessmen and industrialists are three outstanding farm organizations in the United States. Of these, the oldest is the National Grange. It has 800,000 members—men and women, as well as boys and girls 14 years of age or older—in 37 states having state Granges, and in most of the other states and Alaska, in which there are local Granges.

The Farmers' Union represents more than 100,000 farm families in 40 states, in 21 of which it is organized. It has locals in 12 other states, and 300,000 farmers are members of the organization's coöperative associations. A family becomes a member of the Farmers' Union when the head of the family joins and pays his dues.

Formally organized in Chicago, in 1920, the American Farm Bureau Federation, youngest of the three national farm organizations, has 443,850 members in 39 states.

Regional and local interests with which farm people are in daily con-

tact tend to minimize in their minds the services offered by farm organizations that take a national view, which they seek to express in terms of a national policy and program for agriculture. National issues do not possess much vitality until they are defined and understood locally. Membership gains by the national farm organizations in recent years indicate a growing conviction that agriculture's problems are not only human and local but national and international as well.

Agriculture After the First World War

An historic agricultural conference in 1922. Economic conditions that began to identify themselves after the First World War grew from bad to worse, particularly for American farmers. President Warren G. Harding called an agricultural conference. Of the 336 delegates at the conference in Washington, January 22, 1922, 202 were farmers. The delegates represented 20 farm organizations. They included 15 women delegates; 60 delegates from agricultural colleges, state departments of agriculture, marketing agencies, and the farm press; and 62 delegates from business institutions allied with agriculture. Secretary of Agriculture Henry C. Wallace called the conference to order. President Harding, addressing the delegates, said:

> Even in our times and under the most enlightened establishments, the soil has continued to enjoy less liberal institutions for its encouragement and promotion than most other forms of industry. . . . A score or more of manufacturers consolidate their interests under a corporate organization, and attain a great increase of their power in the markets, whether they are buying or selling The farmer, from the very mode of his life, has been stopped from these effective combinations; therefore, because he buys and sells as an individual, it is his fate to buy in the dearest and sell in the cheapest market.

Out of this conference came 37 legislative recommendations, one of which directed Congress and the President to "take steps immediately to establish fair exchange value for all farm products with that of other commodities." (In 1933, Congress was to translate the idea of "fair exchange value" into law.)

Congress authorizes farmer associations. Another Congressional act that resulted from the agricultural conference of January 22, 1922, was foreshadowed in an address made on that occasion by G. Harold Powell, general manager of the California Fruit Growers' Exchange. He spoke on "The Fundamentals of Cooperative Marketing," saying:

> Farmers should have the legal right to organize. To deny such legal recognition by the State and Federal Governments will not help to meet the fundamental necessities of organized cooperation among farmers and will lead to endless conflict and confusion.

On February 18, 1922, the Capper-Volstead Act, approved by the President, authorized association of producers of agricultural products. Section 2 of the act describes how the Secretary of Agriculture shall deal with any association set up under the act that monopolizes or restrains

trade "to an extent that the price of any agricultural product is unduly enhanced by reason thereof." During the 1939-1940 marketing season, 10,700 marketing and purchasing coöperatives in the United States, with a total membership of 3,200,000, transacted business amounting to $2,870,000,000, according to the Farm Credit Administration. Coöperatives handling dairy products led in dollar business done, followed by grain coöperatives, with about half as much dollar business transacted.

Responses to pressure groups. In all instances, the types of service instituted by the Government down to the present time have been in response to insistent demands by various groups. Pressure groups and the ideas and leadership of notable persons are the laboratories of laymen. All pressures, however, are sifted and weighed by many minds before they can take statutory form and go into action. In a democracy, ideas must be discussed and debated, and the public accustomed to them before they can be put to social use. A democracy does not establish institutions and force them upon people. Pressure groups arouse discussion and direct attention.

Continuity of Government farm policy. A remarkable degree of continuity marks the entire history of the Department of Agriculture, in which the new has always grown out of the old. Furthermore, a continuous thread runs through the evolution of agriculture's efforts to develop and progressively improve a national policy and program in the interest of farmers and the general welfare.

Secretary of Agriculture David F. Houston said, in his 1913 report, that "further production waits on better distribution." Secretary Henry C. Wallace, in his 1923 report, held that the nation's wheat acreage should be reduced and diversified farming instituted. Canadian, Argentinian, and Australian wheat, cheaply produced on rich, new land, was competing effectively with United States wheat in foreign markets. Surpluses of important farm crops were increasing; they were the foremost troubles of Secretary of Agriculture W. M. Jardine (1925 to 1929) and of his successor, A. M. Hyde (1929 to 1933). American exports exceeded American imports in the years 1924 to 1928 by an average of $652,000,000 annually, but that sum was nearly balanced by the outflow of capital from the United States. America was financing its own exports with loans, most of which have not been repaid.

Land-use planning proposed. Secretary Hyde called a land-utilization conference, which was held in Chicago, in November, 1931. Two national committees were set up; they were largely serviced through the personnel of the Division of Land Economics, then in the Department of Agriculture. Releases, issued under the sponsorship of the committees, reiterated the propositions that land is vested with a social and public interest, that widespread social and economic maladjustments in the use of land can be corrected only by Governmental policies based on social planning, and that each acre has a socially best use which must be discovered through the process of land planning.

Land inflation and deflation. After about 1914, Midwestern farm real estate in particular rose to borrowing and selling valuations that

could not be sustained by its productive capacity under normal economic conditions. Near the beginning of and during the First World War, farm real estate in the foremost farming regions underwent inflation. Its owners could sell or borrow on it at valuations that had risen from, say, $100 an acre to $300 an acre or more in many localities. Psychologically, these owners had greatly increased their wealth, and debts were contracted and obligations assumed by thousands of farmers who were seriously affected, if not financially ruined, by the postwar deflation.

Nine years after the agricultural conference called by President Harding in 1922, the Department of Commerce reported that the farmer was receiving prices but little higher than before the War, while his taxes had increased two and a half times, machinery cost him twice as much and building materials two thirds as much again, and wages were two thirds higher than prewar levels.

President Hoover's Farm Board. To provide agriculture with a mechanism, like that of other industries, for the orderly production and marketing of farm products was the principal objective of the Agricultural Marketing Act of 1929 It sought to unify the processes of agricultural marketing with the support of loans. A $500,000,000 revolving fund was made available to a Federal Farm Board consisting of nine members, the Secretary of Agriculture being an ex officio member.

At the outset, the Board viewed its chief function as the fostering of coöperative marketing associations. But drastic declines of agricultural prices developed in the latter part of 1929, with the result that the Board, changing its policy, concerned itself increasingly with stabilizing prices of major farm products. It began making loans to coöperatives to enable them to hold commodities in storage until the market improved. Stabilization corporations, set up for wheat and cotton, took over most of the supplies of these products that had been held by the coöperatives. Additional stocks were accumulated by direct purchase in the market. Operations of the corporations resulted in heavy losses to the Board, which began to insist that gains in withholding supplies from the market could be realized only if production were held in line with actual market demand at home and abroad.

Major Farm Legislation After 1932

Handicaps of the industry. Agriculture's recurring difficulties and crises result chiefly from the fact that it is out of adjustment to its climatic, domestic, and international environment. At the crest of the business cycle in 1929, farm products could be exchanged, on the average, for only 91 per cent as much of other products as in the prewar period. During the depression, this disparity was greatly increased. By February, 1933, the exchange value of farm products for industrial goods had fallen to 50 per cent of the prewar average, and their exchange value for taxes and credit was even less.

Agriculture's primary handicaps after the First World War were repeatedly stated by Henry A. Wallace when he was Secretary of Agricul-

ture. They are: Wartime crop expansion through plowing up 40,000,000 additional acres in response to the nationalized slogan that "food will win the war"; the abrupt change of the nation from a debtor to a creditor status; the displacement of the horse and mule by automobile, motor truck, and tractor, which released 35,000,000 acres from producing grain, hay, and pasture for animal power; the movement of European countries to be agriculturally self-sufficient; new competition from Argentina and Australia in America's export trade; the increase in industrial tariffs, resulting in retaliatory action by other nations to shut out American farm products; the growth of corporate monopoly and price-fixing, which made farmers take what was offered for their products but pay what was asked for their purchases. To all these handicaps that Mr. Wallace faced on assuming office may be added such long-time abuses as forest destruction, soil erosion, and inattention to water resources.

What happened thereafter was an effort by the Department of Agriculture to respond to the wishes of the public democratically registered through Congressional enactment. The Department itself could neither plan nor carry out plans; it had to have authority and it could do only, as throughout its history, what Congress directed it to do.

Farmers were powerfully represented by their national organizations in Washington in 1933. Laws were passed to promote water conservation, reforestation, rehabilitation of underprivileged rural people, surplus-commodity disposal, public acquisition and development of land submarginal for agriculture, rationalized farm-credit facilities, development of rural electrification facilities, crop insurance, marketing agreements, tenancy reform, and research to find new uses for agricultural by-products and for crops subject to periodic surpluses.

Agricultural Adjustment Act. National farm-organization leadership supported the legislation known as the Agricultural Adjustment Act, which was approved by the President on May 12, 1933. Congress sought in this act to reëstablish prices to farmers at a level that would give agricultural commodities a purchasing power, with respect to articles that farmers buy, equivalent to the purchasing power of agricultural commodities in a base period which the act defined. Such purchasing power, however, did not necessarily imply that prices of farm products, in dollars, would be the same as they were before the War. It meant that farmers selling the same volume of farm goods would be able to buy, with their returns, the same volume of manufactured goods that they were able to buy in the base period.

Basic farm products. "Basic agricultural commodities" named in the act were: wheat, cotton, field corn, hogs, rice, tobacco, and milk and its products. For all of these, except tobacco, the base period was August, 1909, to July, 1914; for tobacco, it was August, 1919, to July, 1929.[1]

Agricultural leaders were and are mostly agreed that one of the best

[1] Two Department of Agriculture economists pointed out, in 1939, that, "in an age of increasing technology and dwindling foreign demand, probably any base period for parity prices between 1910 and 1930 would likely give unattainable price standards."

periods in the industry's history was from 1897 to the First World War—1914. Commodity prices were rising. In exchange value, basic agricultural and nonagricultural commodities were in approximate balance. Farming had emerged finally as a comparatively stable business. Land values were gradually advancing. An improved physical plant was in operation. Tenure and debt conditions were fairly tolerable. Agriculture's voice in national affairs was beginning to be audible. A cornerstone of the industry was the production of an exportable surplus.[2]

Under the Agricultural Adjustment Act of 1933, processing taxes were authorized on six of the seven "basic commodities" to obtain revenue for extraordinary expenses incurred by reason of the national economic emergency. No processing taxes were ever levied on "milk and its products" for the reason that dairy farmers were unable to agree on a commodity program or plan under the act.

A Supreme Court decision. Processing-tax and production-control provisions of the act were invalidated by the Supreme Court on January 6, 1936, when the majority of the Court handed down its decision in the Hoosac Mills case. In that year, farm leaders and Congress evolved the Soil Conservation and Domestic Allotment Act, which continued provisions of the Soil Erosion Act of 1935. This act provided, however, for more extensive use of soil-conserving and soil-building crops and practices on land taken out of soil-depleting crops that had been grown in surplus. Farmers who took part in the national farm program set up under this legislation received adjustment and other payments from funds annually appropriated by Congress.

Following the invalidation of the 1933 act, the Soil Conservation and Domestic Allotment Act, based on voluntary soil conservation, was approved on February 29, 1936.

Soil conservation and domestic allotment. Coöperating through the national farm program, set up under the Agricultural Adjustment Act of 1938, farmers operate their farms in such a manner as to conserve soil, improve farm income, and protect consumers through fair prices by stabilizing supplies of farm products at levels adequate for domestic, export, and reserve requirements.

To conserve the soil, farmers earn payments for planting a larger part of their acreage formerly in soil-depleting to soil-conserving crops, and for carrying out soil-building practices. Soil-depleting crops include the three great staples of corn, wheat, and cotton, and certain other crops. Soil-conserving crops are grasses and legumes. Soil-building practices include such measures as the seeding of legumes, the application of lime and phosphate, the planting of trees, and the construction of dams and terraces to control water runoff.

In the interests of consumers, the farm legislation provides that farm production of food and fiber will be maintained at adequate levels.

The program aims to increase farm income by providing farmers with a means of stabilizing market supplies and prices of their products

[2] Farmers paid a total tax bill of only $624,000,000 in 1913; in 1921, they paid $1,497,000,000

through acreage allotments, marketing quotas, loans, and crop insurance.

The Ever-Normal Granary, made possible through the loan and insurance programs, provides for the storage of farm products in years of abundance for use in years of scarcity.

Other activities authorized. Strengthened by the act of 1938, the farm program includes conservation payments to producers who plant within their acreage allotments of soil-depleting crops and carry out soil-building practices; parity or price-adjustment payments (when funds are appropriated) to producers of corn, wheat, cotton, tobacco, and rice who plant within their allotments; commodity loans to support farm prices and store reserves; marketing control of surpluses when approved by two thirds of the producers voting; and Federal crop insurance on wheat.

Activities authorized under the act of 1938 and related legislation but administered by other agencies of the Department of Agriculture include: freight-rate investigation and study, purchases of farm surpluses for relief distribution, market expansion through research on new uses for farm products, and the allocation of funds to help maintain a fair share of the foreign market for American farm products.

Operation of the farm program. Operation of the AAA farm program centers around the county agricultural-conservation association, a local administrative unit of the Agricultural Adjustment Administration. All farmers who coöperate in the program are members of their county association and pay its operating expenses out of their AAA payments. Members carry on the business of their association through elected committees—one for each community and one for the county.

The community committee, composed of three farmers elected annually by their neighbor farmers, bears the responsibility for explaining the program in terms of its application to individual farms. Approximately 73,000 community committeemen throughout the country work an average of about 11 days each year in administering the program in their communities or townships.

Farmers serve on county committees. Delegates elected from all communities in the county choose three farmers to serve as the county committee. The county agricultural agent serves either as secretary or as an ex officio member of the county committee. This committee distributes county acreage allotments equitably among farms in the county; approves the soil-building practices for which farmers may earn payments; and, in general, adapts the national program to local conditions. Approximately 9,000 county committeemen do AAA work on an average of approximately 65 days each year.

Linking the work of all county associations in each state are state agricultural-conservation committees. The state committee is composed of three to five farmer members, appointed by the Secretary of Agriculture on the basis of local recommendation, and the director of the State Agricultural Extension Service. Aside from being on a state-wide basis, the duties of the state committee follow much the same pattern as those of the county committees.

Administration on a regional basis. In Washington, D. C., the administration of the program is handled on a regional basis, with a director for each of the Western, Southern, North-Central, East-Central, Northeast, and Insular Regions. The Sugar Division administers the Sugar Act of 1937 for all domestic sugar-producing areas, Continental and insular. The Division of Information serves all regions. The Washington office supplies to farmers from various Government sources the technical aid and information necessary to operate the program; advises with the Secretary in establishing national acreage allotments and goals; and coördinates suggestions made by farmers, through their committeemen, to improve the program-operating procedure.

Through farmer administration, the program serves as a channel through which flow the demands, experience, and knowledge of farmers, making the program constantly more effective.

Financing the farm program. Soil conservation costs money; it cannot be done by farmers who are continually receiving less than a fair share of the national income. The farm program helps farmers to conserve the nation's soil resources and attempts to bridge the gap—until parity of farm income is reached—between the amount farmers receive for their products and the amount they pay for the products they buy. Parity income for agriculture, as defined by law, is that net income from farming operations per person living on farms which bears the same relation to the income per person not living on farms as prevailed in the 5 years before the First World War.

From 1933 to 1935, the program was financed from taxes on the processing of major farm commodities. Since 1936, when the Supreme Court invalidated processing taxes, the program has been financed by appropriations from the Treasury. Payments to sugar-cane and sugar-beet producers, however, are offset by collections of an excise tax on refined sugar.

Latest annual report on farming activities. In its report on activities from July 1, 1939, to June 30, 1940, the Agricultural Adjustment Administration states that 5,756,000 farmers coöperated in the program in 1939 and that, at the end of the fiscal year, more than 6,000,000 were enrolled in the 1940 program. Participation represented a gain of 10 per cent over the number participating in 1938 and 58 per cent over the number participating in 1937. The cropland on participating farms in 1939 represented 78 per cent of all cropland in the United States. Operators included more than 48,000 ranchers in 17 Western states who took part in the range-conservation program in 1939. They operated more than 213,000,000 acres of range land.

Soil-building practices in 1939, according to the report, were adapted to the needs of states and localities in a manner that made definite assistance available to farmers in carrying out the conservation measures most needed on their land. Varying by local areas, emphasis was placed on grasses and legumes, permanent pastures, green manure and cover crops, forest-tree practices, lime applications, superphosphate application in connection with soil-conserving crops, and erosion-control and water-con-

servation practices. The restoration of permanent vegetative cover to farm land was a special phase of the program applicable to wind-erosion areas in ten states.

Soil building reviewed. Achievements of farmers in carrying out the principal soil-building practices under the 1939 program, as listed in the report, included:

(1) 41,429,000 acres of new plantings of grasses and legumes and permanent pasture mixtures.

(2) 25,934,000 acres of green manure and cover-crop plantings.

(3) 352,000 acres of forest-tree practices, including plantings, maintaining and improving stands, nongrazing of wood lots, and, in the Northeastern states, rehabilitation of hurricane-damaged woodland.

(4) Natural reseeding of pastures by deferred grazing on 3,470,000 acres and use of 19,241,000 pounds of seeds in artificial reseeding of pastures.

(5) 25,960,000 acres protected by such erosion-control and water-conservation practices as protected summer fallow, strip cropping, and contour-farming methods.

(6) Construction of 355,000,000 feet of terraces for erosion control.

(7) Application to the soil of 5,792,000 tons of lime and 637,000 tons of superphosphate.

Farmers participating in the 1939 program earned conservation payments, including range-conservation payments, totaling $497,311,000, from which small deductions were made for county-association expenses; and price-adjustment payments on corn, wheat, cotton, and rice totaling $211,742,000. Thus a combined total of $709,053,000 in payments, exclusive of other income gained resulting from the program, was added to the cash income of the nation's farmers for their 1939 adjustment and conservation efforts. Farm buying power in 1939, the report adds, was 72 per cent larger than in 1932 and was equal to that of 1929.

Treasury appropriations. Payments to farmers under the program from 1933 through 1940 (by program years) are given in Table I.

A Program for Range Conservation

Grasslands a national resource. Western range land consists of deserts and plains, mountains and plateaus, and semidesert areas with valleys and tablelands. Grazing on the Western range, once independent and almost wholly pastoral, is now an integral part of Western agriculture. As a whole, the capacity of the range for livestock production is 52 per cent less now than it was in virgin condition. Where once 2 acres sufficed to graze a cow for a month, now nearly 4 acres are required. Hardy short grasses have in varying degrees given way to weeds and shrubs of lower value.

On the public range, cattle and sheep grazing was a big business in . hands before the plows and barbed wire of homesteaders were seen range country. Gradually cattle and sheep, as well as horses, in-

TABLE I

GOVERNMENT PAYMENTS TO FARMERS UNDER THE CONSERVATION PROGRAM

Year	*Conservation Activities*	*Amount Paid Out in Dollars*
1933	Rental and benefit	$208,424,000
	Cotton option and pool	68,466,000
1934	Rental and benefit	636,523,000
1935	Rental and benefit	466,988,000
	Cotton-price adjustment	39,771,000
1936	Agricultural conservation	369,218,000
	Rental and benefit	45,750,000
1937	Agricultural conservation	301,514,000
	Cotton-price adjustment	122,077,000
	Sugar	36,199,000
1938	Agricultural conservation	451,309,000
	Sugar	45,157,000
1939	Agricultural conservation	510,268,000
	Price adjustment	211,124,000
	Sugar (partly estimated)	46,920,000
1940[a]	Agricultural conservation	451,509,000
	Price adjustment	203,018,000
	Sugar	47,012,000

[a] Estimated as of January, 1941.

creased, until the public land was overstocked. In 1935, the range was carrying about 50 per cent more cattle than could be grazed on it without destructive results. No regulation was attempted until 1905, and then it was too late to be effective. About 25 years ago, ranchmen who were overstocked sold thousands of horses at cent a pound. Buyers sold carloads of these horses to Midwestern processors, who exported horse meat and made dog food.

Nearly 30,000,000 of the nation's 68,769,000 cattle, about 40,000,000 of its 54,473,000 sheep, practically all of its 4,032,000 mohair goats, and more than 4,000,000 of its 10,616,000 horses were on ranches and farms in 17 Western states in 1940. Approximately 75 per cent of the national output of wool and mohair, and, in pounds, about 55 per cent of the sheep and lambs, and nearly one third of the cattle and calves are produced on the range. Comprising about 728 million acres, or about 119 million acres less than it was 100 years ago, the range is still nearly 40 per cent of the total land area of the United States. One third of the 728 million acres is Federal range, which is divided among national forests, grazing districts, public domain, and other withdrawals and reservations. Stock raising and grazing and animal-fiber production on private and public

range lands are one of the outstanding sources of the agricultural industry's annual income.

The Taylor Grazing Act. Until the passage of the Taylor Grazing Act, in 1933, the remaining public domain of about 165,000,000 acres was a grazing common. Anyone was free to use it without restrictions, except those imposed by customary rights more or less supported by public opinion, legislation, and the courts. Since the public domain was widely interspersed with privately owned and state-owned land, and since Federal statutes prohibited fencing Federal land, the greater part of the area was unfenced. Inevitable consequences were a continual scramble to get as much grass as possible, serious impairment of range resources, deterioration of herds and flocks, and intensified financial instability due to the lack of provision of feed reserves for unusually dry years.

Effects of excessive grazing. Grazing capacity of the range has been cut down gradually by droughts, overgrazing, rodents, insects, and the encroachment of range-destroying plants—all of which increase soil erosion by wind and water. If the "plow that broke the plains" has a counterpart, it is the cow that broke the range, and the effects are much the same. Short-season annual grain crops replaced the native short-grass cover in the wake of the sod-breaker on the Great Plains. When the perennial grass and shrub cover of the range was destroyed, short-season annual weeds followed—such as downy chess, Russian thistle, peppergrass, or stickseed. In both cases, soil formation, soil binding, and watershed protection have been sacrificed for a short-season annual crop

Recovery of a normal range vegetation is a matter of years at best, and possibly several centuries in areas where the surface soil is lost. Recovery from an early stage of overuse may require only a year or two of adequately restricted grazing to permit the perennial grasses to regain vigor.

Grassland development in the South. Cattle raising on grass, forage crops, and hay is a slowly expanding industry in the eight South Atlantic states, which have 4,778,000 heads of cattle. Georgia, Virginia. and Florida together have 2,723,000 head. County agricultural agents in every Southern state are advocating permanent improved pastures. Not only is the actual amount of forage much less in woodlands than in open pastures, but the feeding value of forage plants grown under forest shade is much less than that of plants grown in full sunlight. A good open pasture supports ten times as many cattle as the same acreage of woodland pasture, but the ratio depends largely on the density of the woods

Range feed shortage. Droughts and a consequent shortage of feed in 1934 caught the range livestock industry overstocked. Totals of cattle and sheep on American ranches and farms, in that year, were more than in any of the previous 13 years. The Agricultural Adjustment Act was amended, declaring cattle to be a "basic commodity," and an appropriation of $200.000,000 was made for a surplus-reduction program. No provision was made for a processing tax. An additional $50,000,000 was used to finance relief purchases of dairy and beef products, and the removal of diseased cattle.

In order to avert the starvation of cattle, sheep, and goats, and to conserve the stricken and overstocked range as much as possible, the Government made feed loans available to stockmen. It also bought 8,280,148 cattle, for which it paid the owners $111,546,104; and 3,609,654 sheep, for which the owners received $7,219,308. Over 350,000 goats also were purchased. About 100,000 animals were turned over by grant to Indian reservations, and about 51,000 were used in rural rehabilitation projects. Meat from these animals that were processed was distributed to families on relief; but cattle numbering 1,485,704, as well as 2,209,638 sheep and 254,731 goats, were condemned as unfit for human consumption because of their emaciated condition, owing to starvation and thirst.

Range-land research. Research in which Federal and state agencies are coöperating is essential to the improvement and conservation of range resources. The key to the maintenance of the range, with its direct and indirect social and economic benefits, is the restoration and correct use of forage and the soil on which it grows.

Results of experiments in range-forage utilization were reported at a Grassland Conference in Texas, in 1940. Comparing income from two range areas of the same size, the first stocked with 1,400 cattle and the other with 1,900 head, the average income over 22 years was $6,000 more per year in favor of the area stocked with 1,400 head.

Range-conservation work under the range program of the Soil Conservation and Domestic Allotment Act relates directly to privately owned range lands and to those state and county lands under direct control of private owners National-forest and grazing-district programs apply primarily to range lands in public ownership, but both aim to coördinate the use of these public lands which the management and use of range land held in private ownership.

Range improvement summarized. Under the range-conservation program instituted in 1936, water development for livestock has been increased, and range-improvement practices have been adopted and continued on a high percentage of Western ranches. More than 48,000 ranchmen, operating 213,000,000 acres of range land, participated in the program in 1939. They improved the stand of grass on about 25,000,000 acres, built nearly 21,000 tanks and reservoirs to control erosion and provide stock water, and constructed 8,000,000 feet of spreader terraces Texas ranchmen, represented in this summary, constructed 5,240 miles of fire guard in 1937, 1938, and 1939. As in previous years, the purpose of the 1941 range program is to conserve range soil to use but not abuse its vegetation.

Ranches vary in size from small acreages to hundreds of thousands of acres. In the last 20 years, the general trend has been toward larger ranches. Experience has tended to indicate the most economical size of ranch units in different regions.

The Farm Security Administration

Program of the Farm Security Administration. Successor to the Resettlement Administration, the Farm Security Administration was created

to help needy farm families become self-supporting. By June 30, 1940, after 5 years of operation, its program of helping low-income farmers achieve a greater degree of independence and security had reached 1,440,000 farm families. The major activity of this action agency in the Department of Agriculture is the rehabilitation of needy farm families through small loans, accompanied by guidance in sound farming methods to insure the best possible use of money so loaned. Under this program, almost $500,000,000 had been loaned to approximately 875,000 families by the end of 1940. Loans are made only to farmers who cannot get adequate credit elsewhere; the money is used to buy seed, tools, livestock, and other equipment necessary to carry on farming operations. Each borrower agrees to keep businesslike records and to follow a sound farm and home-management plan, which he works out with his county supervisor, who follows up with advice on farm problems.

Grants to distressed families. In cases of extreme distress, especially in drought or flood areas, small grants are made for the purchase of food, fuel, and other urgent necessities. In return, the families agree to perform some improvement work around the farm or home, usually in the form of sanitation work.

For farmers overburdened with debt, the agency acts as an intermediary in organizing a local committee of businessmen and farmers, and in bringing the farmer and his creditors together in a friendly atmosphere to discuss their mutual problems. Often it is possible to reach an agreement for extending the time of payment, reducing interest rates, scaling down the debt, or refinancing part of it through a Farm Security Administration loan. Through this service, 139,436 farmers have had their debts reduced by $97,404,007.

Under the rehabilitation program, land-leasing arrangements are being changed from the old 1-year verbal leases to written, long-term or renewable contracts, with agreements that will encourage a tenant to protect the soil and improve the property. The Farm Security Administration is also coöperating with other agencies in the development of a water-facilities program for the benefit of low-income farm families in arid areas of the Western states.

Number of families benefited. Progress made by rehabilitation borrowers is shown in a survey taken at the end of the 1939 crop year. Covering 360,000 families, the study disclosed that, since participating in the program, these families had increased their annual income $58,000,000, or 43 per cent; they had increased their net worth $83,000,000, or 26 per cent; and they were raising $35,000,000 more worth of foodstuffs for home use.

Development of homestead projects. The agency is managing 164 homestead projects, practically all of which were started by the Resettlement Administration and other prior agencies. When completed, they will provide accommodations for almost 14,000 families. These projects are closely related to the agency's main function of rehabilitation, their primary purpose being to give needy farm families a chance for greater security and stability. Some of the projects consist of scattered farms;

others are community projects with farms grouped closely together in the same area.

Migrant camps for labor. With migratory labor camps, the Farm Security Administration is providing a minimum of shelter and sanitary facilities for some of the families forced to follow seasonal farm work. More than 10,000 families at any one time, or between 30,000 and 40,000 families a year, can be accommodated in the 37 permanent camps and 16 mobile camps.

Tenant-purchase program in action. Under the tenant-loan program, authorized by the Bankhead-Jones Farm Tenant Act, of 1937, the Farm Security Administration makes a limited number of loans each year to tenants, sharecroppers, and farm laborers to buy farms of their own in counties where tenancy is most widespread or is growing rapidly. Loans are large enough to enable the borrower to buy a farm and, if necessary, to repair the buildings or put up new ones. By the middle of 1941, more than 20,000 such loans will have been made during the 4 years the program has been in operation.

Housing, coöperatives, and medical care. In completing homestead projects and in carrying out the tenant-purchase program, the agency has developed low-cost methods in the construction of rural housing which have set new standards in that field. Good four- and five-room houses are built for as little as \$1,000 to \$1,500 in the South, and for \$2,500 in the North.

Under a community- and coöperative-service program, the Farm Security Administration makes loans to groups of its rehabilitation borrowers for the joint purchase of equipment and services that they cannot afford individually. More than 16,000 of these small coöperatives have already been formed. Larger coöperative loans have been made to 122 associations or groups, and there has also been considerable coöperative development on the homestead projects. Loans have been made to 33 land-rental coöperative associations, which are formed by farm tenants for the purpose of leasing plantations and then subleasing individual units to members of the group.

In order to safeguard and improve the health of its borrowers, the Farm Security Administration has worked in close coöperation with state and local medical associations to develop a program of group medical care. Under this program, approximately 90,000 families, or 450,000 persons, are now receiving medical care at a small monthly cost they can afford to pay.

Light and Power in Rural America

Developments since 1934. Electric-power lines have spread rapidly through rural America since the establishment of the Rural Electrification Administration, on May 11, 1935. Changes resulting from this new light and power in rural life and culture cannot yet be fully visualized. By the close of the fiscal year 1940, there were 1,128,040 electrified farms in the United States, an increase of 151.6 per cent over the 743,954 reported by

the Edison Electric Institute as of December 31, 1934. More than half of these newly electrified farms were connected to lines financed by the REA; the rest were served by private utilities, which had been stimulated to activity by the growth of the REA program.

Electrification under the program enables rural people to obtain central-station service by means of self-liquidating loans, most of which have been made to farmers' coöperatives, public-power districts, and other nonprofit organizations. Nonprofit service organizations, together with economies made possible partly by taking full advantage of the new high-strength conductors and partly by mass operations, make service feasible in areas too thinly populated to form attractive fields for utility corporations organized for profit. Most of the REA systems buy energy at wholesale from an existing source, usually a private power company. A few of them, lacking an adequate source of wholesale power or unable to obtain it at favorable rates, operate their own, REA-financed generating plants.

Electricity to pay its own way. From the outset, the REA has emphasized productive uses whereby farmers can make electricity pay its own way and often yield a profit. Its efforts in this direction have become more effective as a result of President Franklin D. Roosevelt's Reorganization Plan No. 2, which, on July 1, 1939, made the agency an integral part of the Department of Agriculture. Farm people are learning such of the 300-odd uses of electricity on the farm as promise to be useful and economical under the individual conditions prevailing. Electrical industries are therefore finding a broad and rapidly expanding rural market for many of their products.

Meanwhile, the REA program shows promise of stabilizing agricultural communities by making possible the development of small, local industries. As new coöperative power lines spread out, the REA receives reports of the establishment of small shops and factories along them. Many of these small enterprises process local raw materials. Examples are box factories, woodworking plants, quick-freezing and cold-storage locker plants, canneries, cotton gins, and grain elevators. Others are producing materials vital to national defense. Examples are a carburetor factory, machine shops, cinnabar and coal mines, and oil pumps. All of them are furnishing full- or part-time employment to local people.

Social effects may be far-reaching. It is too early to assess the ultimate significance of the trend toward decentralization which the availability of electric power in rural areas is facilitating. Conceivably, the effects may be far-reaching; they may retard the population movement from rural to urban areas by offering opportunities of employment in their own communities to boys and girls who cannot economically be absorbed by the farm. It is possible to foresee a closer approach to parity of rural and urban income and living standards as a result, accompanied by marked amelioration of both urban and rural slum conditions. In marginal areas, increased cash income, as a result of part-time industrial employment, offers the possibility of more widespread adoption of farm-

ing practices that tend to build up rather than to destroy the topsoil, the nation's most valuable resource.

The Farm Credit Administration

Extent of loans made. Organized in May, 1933, as an agency of the Government, the Farm Credit Administration was transferred under a Presidential reorganization order to the Department of Agriculture in July, 1939. A total of more than $6,870,000,000 has been loaned by credit institutions operating under the supervision of the Farm Credit Administration since May, 1933. Loans outstanding on December 31, 1940, totaled $3,069,000,000. Of this total, more than $2,548,000,000 was in the form of long-term mortgage credit, $381,000,000 in short-term credit, and approximately $93,000,000 in credit to coöperative associations. Of the total loans outstanding to farmers in the form of long-term mortgage credit, $1,851,000,000 represented loans made by the Federal land banks and $648,000,000 loans by the Land Bank Commissioner. The balance of approximately $49,000,000 consisted of loans outstanding from the joint-stock land banks, which are now in the process of liquidation.

Short-term credit outstanding. Of the $381,000,000 total short-term credit outstanding, $172,000,000 represented loans to farmers and ranchers from their local coöperative-production credit associations, while the balance of short-term credit was made up of discounts from the Federal intermediate credit banks for privately capitalized financing institutions, regional agricultural-credit corporations, emergency crop and feed loans, and the old drought-relief loans of 1934 and 1935. The largest share of the total outstanding to coöperatives, approximately $75,000,000, was in the form of loans from the banks for coöperatives. In addition to this amount, the banks had credit outstanding amounting to nearly $26,000,000 in the form of notes purchased from coöperatives under the Commodity Credit Corporation crop-loan programs.

Included in the total loans outstanding from institutions under the agency's supervision was $47,000,000 in loans to members of Federal credit unions. Most of the Federal credit unions are made up of urban rather than rural groups.

Loans and credit extensions in 1940. During 1940, the Federal land banks and the Land Bank Commissioner made 39,000 farm-mortgage loans totaling $101,000,000; production credit associations made 231,000 loans totaling $350,000,000; the banks for coöperatives extended credit to coöperative marketing, purchasing, and business-service associations totaling $126,000,000; and the Federal credit unions made loans totaling more than $100,000,000.

The Food Stamp Plan

Number of people served. The Food Stamp Plan of the Department of Agriculture is the newest of its surplus-removal programs. It moves

farm surpluses into the homes of families who need them. In doing this, it broadens the market for food products, thus helping farmers; provides more adequate diets for needy families, thus helping consumers and building up national health defenses; and moves all surplus commodities through regular channels of trade, thus helping business.

The Food Stamp Plan grew out of the direct purchase and distribution programs whereby price-breaking surplus farm products are bought and given to state relief agencies for distribution to people receiving public aid and for use in school lunches. Direct distribution continues for needy families wherever the Food Stamp Plan is not in operation and for school lunches everywhere.

Tenure of the plan. The Food Stamp Plan is an efficient surplus-removal program, first inaugurated on May 16, 1939, in Rochester, New York. On March 18, 1941, it was in operation in 281 areas throughout the nation, serving upward of 3,000,000 people. Forty-seven other areas have been designated and are shortly expected to be in operation. Responsible authorities in hundreds of other centers have filed requests with the Surplus Marketing Administration that the plan be instituted in their communities.

No question has been raised about the need for more food and a greater variety of it among lower-income consumers. It is estimated that 45,000,000 people in the United States are living below the food-diet danger line. Many of these are children.

Two kinds of stamps used. The Food Stamp Plan gives an increase of 50 per cent in food-buying power to needy families in the form of special surplus-food order stamps. Families receiving any kind of public assistance may participate. Two kinds of stamps are used. Participants buy orange-colored stamps in the approximate amounts they formerly spent in cash for food. These are good at any grocery store for any food. With every dollar's worth of orange stamps bought, 50 cents' worth of blue stamps are given to the family free. These are good only for foods currently designated as "in surplus," which are mostly dairy and poultry products, wheat and other cereals, fruits and vegetables, and meats.

Orange-colored stamps are sold to make sure that families using them will continue to buy as much food as they did before the plan was adopted. Free blue stamps, therefore, represent a net increase in the amount of food which is bought and eaten. Farmers get a new market, and the underfed get a better diet.

Market outlet enlarged. The plan provides an important market for farmers and promises a greater market in the near future. Blue food stamps bought more than $7,000,000 worth of surplus farm products in January, 1941. In the 7 months from July 1, 1940, through January 31, 1941, blue stamps were used to purchase more than $37,000,000 worth of farm surpluses. Since the inception of the program, nearly $54,000,000 have been added to the food-buying power of low-income families.

By the end of this fiscal year—June 30, 1941—when the Food Stamp Plan is expected to be working in 350 areas or more and serving around

5,000,000 persons, indications are that it will absorb annually at least 60,000,000 pounds of butter, 80,000,000 dozen eggs, 275,000,000 pounds of pork products, and immense quantities of fruits, vegetables, and other commodities.

Latest figures, on the basis of 3,000,000 participants, show that, in January alone, blue stamps provided a market for 2,735,000 pounds of butter, 3,609,000 dozen eggs, 10,354,000 pounds of pork, 4,738,000 pounds of lard, 32,521,000 pounds of wheat and other cereals, 37,880,000 pounds of vegetables, and 25,127,000 pounds of fruits. When 5,000,000 persons are participating, these figures, naturally, will increase accordingly.

Flexibility of the plan. Built on an "accordion" basis, the plan can contract or expand at need. In times of full employment, it can be operated at a minimum cost but kept in existence for times of depression, when food must move quickly to large numbers of unemployed. It follows, of course, that farmers would also be protected against a sharp decline in the domestic demand for their products.

The plan is administered by the Surplus Marketing Administration and its four regional offices in Dallas, Milwaukee, Philadelphia, and San Francisco. In the various Stamp Plan areas, local welfare agencies are responsible for the designation of eligible participants and coöperate with the agency in the issuance of stamps. The stamps may be redeemed through local banks or agency offices.

Food-stamp areas are operating in every state except West Virginia. The areas range in population from New York City to towns and counties with a few thousand inhabitants. Geographically, they range from small towns and counties to entire states. Six Western states—Arizona, Nevada, New Mexico, Oregon, Utah, and Washington—have adopted the plan on a state-wide basis.

Generally commended by all interested groups, the Food Stamp Plan has been favorably acted on in conventions of national farm organizations and by many others, including milk producers, retail-grocers' secretaries, fresh-fruit and vegetable associations, county officials, and the Congress of Industrial Organizations It has also been editorially endorsed by a large number of newspapers, including farm papers.

Science in Agriculture

Caring for the land. Having achieved a greatly increased and expanding power to produce in excess of available market demands for its principal products, agriculture has a new liability as well as an asset. Seeking equality with labor and industry in the national economy, organized farmers are actively buttressing their case for "a fair share of the national income." Most farmers are prepared to explain why they do not and cannot farm as well as they know how and, at the same time, do a better job of taking care of their land in a country where wind and water erosion takes a vast annual toll of a vital resource.

An old English slogan was: "Feed your land when prices are high and bleed it when they are low." It was possible for farm owners, as well

as tenants operating under long-term leases, to adhere to this practice in the England of Chaucer. In that period, well-farmed good land, in a small island where soil erosion was and is negligible, could stand 5 years of "bleeding" to tide the operating owner or tenant over a depression. American farmers are mostly agreed that, on the basis of their annual cash income, they cannot meet fixed charges, bear the cost of living, rear and educate their children, and, at the same time, maintain the productivity of their land, and keep their buildings, structures, and machinery in repair. For the United States as a whole, the cost of feeding, clothing, and educating a child until 15 years old on a farm is about $2,250.

Making good things better. American farming as a business is under the directive and powerful influence of science. America is rich in good things for better living on farms and ranches, in towns and cities, and on ships at sea and in the air. Applied science is improving good things. American genius, flowering out of racial mixtures of most of the peoples of the earth, is endlessly inventing new things.

Approximately $605,000,000 have been spent by the Department of Agriculture and the state agricultural-experiment stations for agricultural research since 1910. This expenditure represents half of 1 per cent of the national income from agriculture. Some industries spend 3 per cent of their income for research. Agricultural research has increased, but it still lags behind industrial research. In the past 30 years, private industry has paid out five times as much as agriculture has spent for research. More than 7,000 insect species plague farmers. Some 5,000 grasses must be tested intensively by scientists to harness them to cultivation and to find species that grow well, provide good ground cover, and produce maximum forage.

Regional research laboratories. Four regional laboratories, authorized by Congress in the Agricultural Adjustment Act of 1938, for research on the utilization of farm products, have been recently built and are now in operation. They are instituting investigations to develop new and wider uses for agricultural products. Their initial work is concerned with the principal surplus crops in each of the four major producing areas of the country. At Peoria, Illinois, the Northern Laboratory has begun its studies on corn, wheat, and agricultural wastes; at New Orleans, Louisiana, the Southern Laboratory studies cotton, peanuts, and sweet potatoes; at Wyndmoor, near Philadelphia, the Eastern Laboratory studies tobacco, apples, potatoes, milk products, vegetables, hides, skins, tanning materials and leather, and animal fats and oils; and at Albany, near San Francisco, the Western Laboratory studies fruits, vegetables, potatoes, wheat, alfalfa, and poultry products and by-products. These laboratories are operated by the Department's Bureau of Agricultural Chemistry and Engineering.

Increasing the nation's wealth. Working together through the state agricultural-experiment stations and the Department of Agriculture, scientists are expanding the nation's wealth. Other scientists are increasing knowledge of how, through better diets and sanitation, to protect and safeguard health, with the result that rising standards of living are

credited with a rising average age of the nation's population. Scientists in many other state and Federal agencies and in municipal governments are contributing to the development and efficiency of the nation's organized effort better to serve the general welfare. Accomplishments of scientists employed in research laboratories maintained by leading industries operated for profit are prolific.

Science is fathered, mothered, and nurtured by all modern nations. It has been defined as amoral, or outside the bounds of that to which moral distinctions or judgments apply. Modern science, however, is increasingly concerned with people and their welfare in the world of today. All sciences are man-made, and many scientists in all fields are conscious of having a large responsibility to help bring together the principles of science and those of democracy in a dynamic pattern of social organization within which all may find opportunity and justice.

Hazards of Modern Farming

Agriculture's principal hazards. Agriculture as an industry includes more than 100 separate commodities. It is more hazardous, more individualistic in its personnel, more competitive within itself, and more accustomed to producing all it can than any other industry in the national economy.

Agriculture's annual income is reduced in varying degrees and in different areas by one or more such agents as drought, plant and animal diseases, floods, hailstorms, fires, wild animals, poisonous plants, and thieves. Farm fires take a toll of 3,500 lives every year, or nearly 9 a day, and rural property valued at $25,000 is destroyed every hour. Ten per cent of agriculture's yearly income in Iowa, Illinois, Indiana, Missouri, and Ohio is offset by fire and accident losses.

Mechanization has increased the occupational hazards of farming. More people are accidentally killed in farming than in any other industry. During 1937, 38 per cent of Kansas farm accidents occurred in the operation of machinery, 26 per cent being attributed to livestock and 15 per cent to falls. Deaths in Kansas resulting from farm accidents during the period from 1930 through 1939 totaled 854. Although the leading cause was machinery, injuries caused by animals and horse-drawn vehicles exceeded the machinery fatalities. Illinois, in 1938, had an increase of about 50 per cent in farm accidental deaths over 1937. Mechanical safeguards and accident prevention for persons engaged in farming have received but scant attention.

Accidents in barnyards. Fifty per cent of all farm accidents in a central New York farming community, as reported by a physician, in 1939, to the *Journal of the American Medical Association*, occurred in the barn or barnyard in connection with routine chores. July and August were the peak months for accidents to farm people. Ten times as many males as females were injured. For those seriously injured, the hospitalization period was 5.7 days and the number of outpatient visits was 18.3. Monetary loss incidental to a bad injury was, for most farmers, a serious if

not permanent catastrophe. Twenty per cent were unable to pay anything for hospitalization and professional care.

In a number of states where 70 to 85 per cent of the people live in the country, there is but 1 doctor for every 1,000 to 1,500 people. Thousands of farm families live too far from hospitals for safety. Group-health and hospitalization plans have made it possible in recent years for more sick or injured persons to pay for their own care than was previously possible.

Losses from theft. Automobiles, trucks, and improved roads facilitate organized thieving in rural communities. Portable personal property owned by farmers is valued at millions of dollars. Such property commonly has no police protection except from the sheriff's office. Consequently, property annually stolen from farmers mounts up to formidable totals, which cannot be estimated in dollars alone.

Agriculture's roads to town. American agriculture has been profoundly affected during the last quarter of a century by the gas engine and by hard-surfaced roads. In 1940, surfaced and unsurfaced roads in the United States totaled about 2,965,000 miles. Only 3.4 per cent of farmers in 1930—and perhaps 5 per cent by 1937—were located on concrete or brick roads. Macadam roads provided nearly 5 per cent of farmers with year-round service in 1930, and gravel roads served 20 per cent of the farms.

One third of the nation's farms had roads of a quality of gravel or better on April 1, 1930. Improved dirt roads adjoined 29 per cent and unimproved dirt roads 36 per cent of the nation's farms in 1930. In the Great Plains states, 80 to 90 per cent of farmers lived on dirt roads. Many of these farmers doubtless had hard-surfaced roads part of the way to town.

Drains on farm income. Farming as a business loses annually much of its basic capital through soil erosion. It loses additional soil fertility through the growing of soil-depleting cash crops that leave the farms of their origin when sold.

Machinery, buildings, and fences depreciate on farms. Repairs and replacements must be made. Agriculture's income has seldom provided adequately for "obsolescence of plant" except at the expense of farm-family living standards. Eleven-year records on 720 farms in eastern Iowa show that the maintenance of the owners' houses, barns, fences, water systems and tiling cost an average of $2 an acre. Figured on the present value of the improvements themselves, the cost was 5 per cent a year. On small farms, the maintenance charge was higher, reaching $3.03 an acre. Between May 12, 1933, and December 1, 1934, the total farm-mortgage debt in the United States averaged about $8,000,000,000. On January 1, 1940, farm mortgages in the United States totaled $6,910,000,000, the smallest amount outstanding since 1919. Included in this total were the Farm Credit Administration's farm-mortgage and other loans to farmers and farmer coöperatives amounting, in September, 1940, to $3,232,726,513. Privately owned farm real-estate taxes in 1930 were

estimated at $566,000,000, which figure is still fairly reliable, although total property taxes have declined since then.

Trade barriers among the states. American agricultural prosperity and the well-being of the nation's great city populations are bound with the maintenance of the nation-wide market that is made possible by free internal trade. Restrictions, however, of this trade are so numerous and severe that they seriously threaten free trade within the United States.

An urge to protect local industries and local producers is always present. Most trade barriers have been promoted by local groups of producers with the motive of keeping as much of the local market as possible for themselves by preventing or hindering the sale of competing products originating in other states.

Agricultural producers are harmed in two ways by these market-exclusion practices. First, although they may be able to get some measure of protection in their local markets, producers are harmed by similar retaliatory measures in outside markets to which they might want to ship their surpluses. Second, the monopolistic advantages gained by market exclusion are likely to be short-lived.

War expands farm exports. January of this year (1941) was the fifth sucessive month in which farm exports moved out at a rate of only $240,000,000 a year, which is less than one third of the average (about $750,000,000) for the 5 years just preceding the outbreak of the Second World War. Farm exports, in this 5-year period, were far below those of any other 5-year period since the turn of the century.

Passage of the Lend-Lease Bill, however, foreshadows an expansion of exports. Coupled, as it appears to be, with a growing shortage of certain foods and tobacco in the United Kingdom, and implemented, as is apparently the intention, by substantial appropriations earmarked for agricultural products, the bill might more than double the present rate of export of farm products.

Without a lend-lease program, the United Kingdom would still be the sole market to which United States farmers could reasonably look for any substantial export increase, at least while the war lasts. All other foreign markets are either cut off from United States supplies, are unable to afford or unwilling, as a matter of policy, to use United States commodities, or are well supplied from local sources with the type of products this country has to sell.

Poor land heavily taxed. In 1940, 30 of Iowa's 100 country agricultural planning committees found, almost without exception, very little relationship between the assessed value and productivity of farm land. Furthermore, they found only slightly more relationship between assessed value and sale value. Without exception, they found a marked tendency for all land to be assessed very near a predetermined township-average value. Where there are differences in the quality of land, good land is bearing much less of the tax burden in proportion to its income-producing capacity than poor land. Where good land is assessed at from 40 to 65 per cent of its sale value, poor land in some instances has been assessed as much as 600 per cent of its sale value.

Cash expenditures by farmers. One fifth of the automobiles, one third of the trucks, and 2,000,000 tractors in use in the United States in 1940 were owned by farmers, who bought 5,000,000,000 gallons of gasoline in that year. For feed, fertilizers, labor (money wages), machinery, and electric power, farmers spent a total of nearly $3,000,000,000 in 1929. (Their hired labor bill for 1939 was $542,000,000.) They spent over $700,000,000 in 1929 for interest and commissions on loans, including mortgage debts. When to this are added expenditures for livestock bought, for seed, for food, clothing, and shoes, for spraying materials. containers, lumber ($167,000,000 in 1924), and other items—for which no Census figures are available—it seems probable that their annual cash expenditures total about half of agriculture's gross annual income.

Diets of farm and city people. Nutritionists find that there are more poor diets in cities than on farms, but, taking all parts of the country together, 25 out of every 100 farm families not on relief get the kind of meals that are below the safety line. Food takes the biggest chunk out of the average farm family's budget. Families with the very best diets spend little more in actual cash for food than those with the worst diets Diet differences come in the foods produced at home. Families with the best diets grow more than twice as much food at home as do those with the worst diets. Seven to 8,000,000 farm people get diets that fall below the safety line of adequate nutrition as defined by scientists in the Department of Agriculture.

Farm-tenancy trends. In an exceptionally prosperous farm community, tenancy increased from 39 to 52 per cent in the 15-year period between 1915 and 1931, and the age of owner operators increased. In 1915. 94 per cent of the tenants declared their intention of becoming landowners, while in 1930, the percentage dropped to 45. Tenancy has been increasing at the rate of about 40,000 farms a year.

Farm land rented in 1935 constituted more than 45 per cent of all farm land in the country, as compared with only 31 per cent in 1900. Tenants, including croppers, operated 42 per cent of all farms in 1935, as compared with 25 per cent in 1880. Rent paid by farmers in the United States to nonfarmers in 1935 is estimated at $699,000,000 and at $829,000,000 in 1937. Mortgage debt is an increasing proportion of the value of farm real estate. In 1880, the equity of farm operators in farm real estate in the country as a whole was about 62 per cent of the value of all farm real estate. By 1930, the proportion had fallen to 41 per cent, and to 39 per cent by 1935.

More farmers than farms. An almost constant displacement by machines of persons who were at one time stabilized on farms has been taking place. A Midwestern farm journal, in March, 1941, pointed out that more farmers are hunting farms than there are farms to rent, stating:

> Some landlords will be able to squeeze out cash rentals that absorb most of the Agricultural Adjustment Administration's benefits. County AAA committees can check some of this robbery, but it is hard to do so. The only remedy may be State legislation to penalize absentee owners to break up big estates and to increase the number of farms. More tenants drifting to town to get factory jobs would help, too.

Kansas, Oklahoma, North Dakota, Michigan, and Missouri have constitutional or ordinary legislation on the subject of large land holdings within their respective borders.

Population increasing on poor land. Tens of thousands of miners returned to farming after 1929. Most of the farms they opened up were on poor land. Nearly 100,000,000 acres in use in 1930 were unfit for crops. About 650,000 families, containing 400,000 youth, were living on this land. About 500,000 farm families are on land so poor that it will not maintain a decent standard of living. A high rate of natural increase of population occurs among these families, and they do not tend to emigrate.

Public purchase of submarginal land is held to be justified in many areas where families are handicapped by inadequate natural resources. In order to eliminate unnecessary public expenditures for roads, schools, electric-power lines, and other public services in such areas, a program of Federal purchase of land aimed primarily at these objectives was carried out for several years following 1934. Relief funds were used in acquiring over 9,000,000 acres, mostly farm land, which was improved for use as forests, recreation areas, game refuges, ranges, and other purposes. Under the Bankhead-Jones Farm Tenant Act, Congress authorized the expenditure of $50,000,000 over a 3-year period for these purposes, but only about one third of that amount has been appropriated.

Land purchases for reforestation. In the opinion of the National Forest Reservation Commission, one third of the nation is best adapted to forests, and bringing this land under efficient forest management will yield substantial and permanent social and economic returns. Forests, the Commission points out, are the only natural resources that can be widely and readily regenerated at reasonable cost. It adds that the self-support of people and communities has declined as timber and other resources have been removed. Land approved by the Commission for purchase is administered by the Forest Service of the Department of Agriculture. From the outset, in 1911, the purchasing units have bought 17,793,134 acres in 33 states and Puerto Rico, at an average price of $3.75 an acre.

Land Under Irrigation in the Public Interest

Progress under the Reclamation Act. An area constituting two fifths of the United States is too dry for crop production. Since the Reclamation Act went into effect in 1902, about 40 years ago, reclamation projects have added $2,657,000,000 to the nation's wealth through crop production. About 20,000,000 acres are irrigated, west of the 100th meridian; approximately 43,000,000 acres may eventually be irrigated. This total includes land now irrigated and 2,500,000 acres within areas to be served by projects under construction.

Private enterprise has brought 17,730,674 acres of Western land under irrigation

Assisting farmers to transfer from hazardous dry land to irrigated

areas is held to be justified by social and economic policy. In 1936, about half of the acreage of cropland in Federal reclamation projects produced hay and forage. Irrigation is a limited but slowly increasing factor in the nation's agricultural industry.

From 1902 to 1940, millions of acres of land have been retired from agricultural production. Retirement has been brought about through purchase by Federal, state, and city governments, and through water and wind erosion and flood-control measures. Much of the land thus retired from private ownership and commercial production is undergoing reforestation and is being developed into national, state, and municipal parks, experimental forests, and wild-life sanctuaries. Some of it is used for watersheds and reservoirs to serve cities; some is used in connection with hydroelectric-power production for suburban homesites and for Government military and peacetime establishments, new roads, and airports.

Expenditures for Federal relief in the last 7 years in the 17 states[3] represented by the National Reclamation Association were nearly $2,500,000. According to the Association:

> Some 275,000 good homes have been made possible by irrigation, and it can give 275,000 more. Since 1930, facilities have been completed to bring into cultivation 381,000 acres of desert land New storage works have been placed in operation to supplement the irrigation supply for an additional 304,000 acres which were previously inadequately watered.

In 1939, about 22,000 deep-well pumps and about 49,000 other pumps were used for irrigation. Deep-well pumps increase costs but make irrigation possible where there is a permanently lowered water table. More significant is the increasing use of portable sprinkling systems to supplement rainfall, to augment surface irrigation where water distribution is uneven, and to water rough land where gravity systems are not practicable.

Irrigation makes homes and a living. At least 6,500,000 people have been able to make homes and a living in the West as a result of present irrigation. Total appropriations and allocations to the Bureau of Reclamation (in the Department of the Interior) from 1902 to 1936—a period of 34 years—were $537,000,000; from 1937 through 1941, they were $307,000,000. In 1939, the Western and Pacific states afforded a market for non-Western agricultural and manufactured products valued at more than $1,500,000,000.

Drought usually is thought of as being a handicap only to Western farming But farmers in the humid East—particularly truck farmers, gardeners, and orchardists—often are seriously affected by summer droughts. Rainfall records over a 20-year period at 18 locations in 18 Eastern states show that, on an average of once in 7 years, there was a period of 6 weeks or longer when not more than one-quarter inch of precipitation fell in any 24 hours A similar period of 28 days or more occurred every 2 years.

---

[3] Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming.

To offset insufficient rainfall during vital periods of crop production farmers in the East are installing various kinds of irrigation systems

The Lure of Land and a Living

Part-time or subsistence farming. Chiefly as a result of agriculture's increasing mechanization, farms in the most favorable areas for crop production tend to become large commercial farms or small subsistence farms Between the two is the family or middle-sized farm, which has tended to disappear in one or the other of the two groups. Farms vary in size from a few acres to thousands of acres. A decrease of 3.1 per cent in the number and an increase of 7.5 per cent in the size of farms occurred between the 1930 and 1940 Censuses. In the wheat, corn, and cotton belts, farms are much larger than those in diversified farming regions The most economical size of farm to operate in a given area depends on many factors.

Many families with small incomes can lower their living costs by living on a small piece of land and growing their own food, and at the same time enjoy a greater quantity and variety of fresh and canned vegetables and fruit. Gardening and poultry raising on a small piece of land is about all an employed man and his family can care for by hand. About 1 acre of good land is enough for such purposes. But if the family wants to keep a cow and plans to buy the necessary winter feed, 2 additional acres of good pasture land should be enough, and the extra work will not be excessive.

Men employed only part time or for short hours who have large families and small incomes may find it economical to keep a milk cow or milk goats and some pigs, and raise the necessary feed in addition to having a garden and keeping poultry. This plan means the use of horse or mechanical power and should be tried only after experience and careful consideration. Some families are so placed that their best plan involves obtaining a fairly large acreage of cheap land for general farming.

Factors to be considered. Farming and wage work in combination off the farm, now usually called "subsistence farming," attract families with several children who find it difficult to provide suitable housing and plenty of fresh fruits and vegetables from their small incomes. It is much less attractive if wages from work off the farm are not enough to meet the necessary cash expenses of the farm and the family living. Inexperienced people will find severe competition if they try to raise farm products for sale.

Many people now in town who lived on farms in their childhood inquire about subsistence of "self-sufficing" farming on 20 to 100 acres or more. Many farms, apparently suitable for such a purpose, are for sale at relatively low prices, but many serious problems are involved in this kind of farming.

Location of land with regard to community improvements—such as roads, schools, churches, and electric-power lines—should also be considered. A part of the cost of some improvements, such as paving and

sidewalks, is often assessed against the adjoining property. This should be considered when deciding between two tracts of land, if only one has city improvements. The amount of the tax levy for recent years and the probable future taxes should be investigated.

County agricultural agents or farm advisers and agricultural colleges in states where these farms are located are qualified to give helpful advice and information to those who consult them. Subsistence farming may easily be regarded too optimistically by many townspeople.

Increase in small farms. Automobiles and good roads have encouraged many factory workers, professional people, and businessmen to live on a small place a few miles out of cities, have a garden, keep some chickens and occasionally a cow, and thus supply part of the family food. Many such places are reported by the Census as "farms."

Between 1920 and 1935, an increase of 99 per cent occurred in farms of from 3 to 10 acres and of 35 per cent in farms of from 10 to 20 acres Much of this increase took place near towns and cities; but farms of all the larger size groups decreased in number, except for a 2-per cent increase in farms of 175 to 259 acres and an 18-per cent increase in those of over 500 acres. Apparently the automobile has increased the number of small farms more rapidly than the tractor has increased the number of large farms. Small-scale farmers in various regions earn considerable cash by doing nonfarm work. No measure of such income exists.

Farm-engineering and farm-management specialists are studying the possibilities of new, small-scale processing machinery for coöperative use by owners and renters of small farms in comparatively thickly populated rural communities.

Possible extension of craft work. American farmers in pioneer and later times grew plant and animal fibers, which they worked into homemade clothing. Small-scale industry of this type has shifted from farm homes to large-scale commercial units. Now an apparent need is for intermediate units to serve communities and producers of rougher types of cloth and certain craft materials. England has perfected a complete line of machinery for handling certain fibers from opening to final weaving. Such machinery uses from 5 to 20 persons and fits into coöperative communities where home- and fancy-craft products are made.

Machines of this class need not emphasize labor saving, for they would be used in communities in which labor is plentiful. Nor is volume of product per hour or day of primary importance. The machines would not compete directly with industrial machines used in large-scale manufacturing.

Abandoned farms in sloping areas. American experience has proved that, although virgin soil on sloping land may be productive for a considerable time, fertility is not such as to give large yields for an extended period. Cleared uplands usually yield fairly well for a few years and then decline. Their lessened productivity is due, not only to the leaching of soluble salts from the soil, but also to the loss of the soil itself through erosion. In native agriculture, the decline is so rapid and severe that, in most places, lands are abandoned after from 3 to 7 years of

farming. New lands are then cleared and the old ones permitted to revert to brush. "Abandoned farms" number many thousands in the United States. Many of these farms have been repeatedly bought and sold or abandoned.

Farm real-estate values. A slight rise in the national average of farm real-estate values occurred during 1940. The preliminary index of average value per acre of farm real estate was 86 as of March 1, 1941, as compared with 85 on the same date a year earlier and with 84 in 1939. The period from 1912 to 1914 equals 100. Of the Department of Agriculture's series during the last 20 years, the low point was 73 in the year 1933. Values increased about 16 per cent during the next 4 years, but have fluctuated little since 1937. Now the national average is approximately 18 per cent above the 1933 low point. Largest gains in real-estate values since the low point in 1933 have been made in the East South-Central, South Atlantic, and East North-Central states. The smallest rise from the depression low has been in the West North-Central states, where the index of value is now 67, as compared with 64 in 1933.

Negroes and Indians in Agriculture

Land farmed by Negroes. During their 70 years of freedom in this country, Negroes have made remarkable progress in education and economic attainments. In 1935, Negroes were full owners of 150,000 farms, valued at $165,667,000, and part owners of 25,952 farms in the Southern states Combined, the two groups of farms aggregated 10,534,000 acres

Agriculture in most of these states has long depended and still does depend largely on the field and domestic labor of Negroes. Technology, however, has gradually decreased the demand for Negro agricultural labor in the South. Negro farm families shrank from 923,000 in 1920 to 816,000 in 1935 Between 1910 and 1920, over 300,000 Negroes found work in Northern cities; and in the last 20 years, many of these people have continued to move out of agriculture into Northern cities, where their children have fair-to-good educational opportunities.

About 12 per cent of the nearly 54,000,000 people classified as "rural" in the nation's 1930 census were Negroes. In the cotton belt in that year, about 33 per cent of the rural population and 37 per cent of the farm population were Negroes, but the decline in Negro farm population in the United States was from 5,100,000 in 1920 to 4,680,000 in 1930.

Negroes number 7,778,423, or 30.9 per cent of the total population of the 11 states of Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, and Louisiana. In the rest of the states, they number nearly 4,000,000. Of the 2,000,000 cotton-farm families, more than one half are tenants, and tenancy is increasing faster among the whites than among the Negroes. In the 11 states named, there are 300 Negro county agricultural agents; in the cotton-adjustment work under the AAA program, 2,834 of the 7,545 workers are Negroes.

Indians in a coöperative program. Approximately 361,000 Indians are citizens of the United States; Eskimos, Indians, and Aleuts number

about 32,000 in Alaska. Indians live in each of the 48 states, but 62 per cent of them reside on reservations that have been designated for Indian use in 23 states, and over half of this population is concentrated in Oklahoma, Arizona, and New Mexico. In Alaska, very little agriculture is carried on by natives, but in the continental United States, where Indian land holdings total 55,000,000 acres, Indians depend primarily on the land for their livelihood. Livestock raising is their principal industry. About 75 per cent of Indian land is grazing and forest areas, only about 10 per cent being tillable. Of the $9,250,000 income resulting from the agricultural activities of Indians during 1939, approximately two thirds was derived from livestock.

Misuse had seriously depleted the land resources of the Indians, and leasing to non-Indians had grown to an alarming proportion, when, in 1933, the Government's new program for Indians moved toward making these people self-supporting members of their communities. Federal action is enabling Indians to practice conservation and to make intelligent use of Indian-owned natural resources. Many are now taking part in the conservation phases of the national farm program. Gradually the leasing of their allotments is being discontinued, and land is being obtained for many landless Indians. Irrigation, subjugation, and soil-saving systems are being installed. Agricultural credit and opportunities for technological assistance and training have been provided. Co-operative enterprise is being developed to advantage. Livestock is increasing in number and quality.

Indians are competing favorably in a number of communities with other citizens engaged in agriculture. Indians won 2,200 county or state prizes for agricultural exhibits in 1939.

Other Government Aids to Agriculture

Reciprocal-trade agreements. According to the Department of Agriculture's Office of Foreign Agricultural Relations, exports of United States agricultural products have been increased materially as a direct result of the present reciprocal-trade-agreement program initiated by the Department of State in 1936. Of the total value of United States foreign trade in agricultural products in the past 4 years, exports amounting to at least $100,000,000 and imports of about $20,000,000 are directly attributable to these agreements with 21 countries in South and Central America and Europe. For agricultural products, the domestic market has been expanded by the agreements, and they have yielded indirect benefits to United States farmers.

New types of fertilizers. An act of Congress, in 1933, created the Tennessee Valley Authority as a corporation, directed by statute to take custody of the Wilson Dam and appurtenant munitions plants at Muscle Shoals, Alabama, and to operate them in the interest of the national defense and for the development of new types of fertilizers for use in agricultural programs. A further provision of the statute is for the development of the Tennessee River, which is 650 miles long and, in 7

states, has a basin comprising 41,000 square miles. Two thirds of the 2,500,000 people in the basin are classified as "rural." The corporation is authorized to employ the war properties at Muscle Shoals in order to "improve, increase and cheapen the production of fertilizer and fertilizer ingredients." Plant-food material produced by the corporation has been made available for use by agricultural research and agricultural educational agencies in 47 states, Hawaii, and Puerto Rico. Material supplied by the corporation is being distributed by the Agricultural Adjustment Administration as grants-in-aid under its national program of soil conservation. Under supervision of land-grant institutions and their affiliated agencies, plant food had been applied, as of July 1, 1940, to 30,683 farms aggregating nearly 5,000,000 acres, for testing and demonstration purposes in 652 counties in 23 states.

Agriculture's educational facilities. Institutions and facilities in the United States for vocational guidance and training, and for education in agriculture, domestic science, and home economics, are unequaled. They have long had the support of the farm press and national farm organizations. Agriculture as a business draws its most effective personnel from agricultural-college graduating classes. These institutions, set up and maintained jointly by the state and Federal governments, attract good-to-exceptional talents and train them for the technical and operational staffs of private and public agricultural business. Many agricultural-college graduates are members of national, state, and local farm organizations. Extension education, demonstration, and 4-H Club work by trained men and women in Federal and state coöperative services deeply influence the life and welfare of the nation's rural population.

Inter-American agricultural activity. The Department of Agriculture has had a long record of coöperative effort along lines of inter-American agricultural activity, extending back nearly half a century. In the last 5 years, this activity has increased rapidly through the lending of agricultural experts to Haiti, Paraguay, Colombia, Ecuador, and other countries. It has culminated in the establishment of a Division of Latin American Agriculture in the Department.

The 76th Congress passed five outstanding laws designed to improve American relations with Latin America. These laws authorized: (1) the loan of experts to other American republics on request; (2) the carrying out of provisions of the Buenos Aires and Lima conventions; (3) the provision of a $500,000 appropriation for rubber research, leading to increased production of this strategic material in the Western Hemisphere; (4) the establishment of a scientific-study center in the Panama Canal Zone; and (5) the increase by $500,000,000 of the amount of loans that the Export-Import Bank may have outstanding to government and other agencies of the Western Hemisphere to assist in developing their resources, stabilizing their economies, and marketing their produce.

Eighteen Latin-American students and professors are studying in the United States, as a result of scholarships and travel grants arranged

through the State Department. This is a part of the program to increase the interchange of students and teachers between the American Republics.

Agriculture's Share of the National Income: The Crux of the Farm Problem

Agriculture's cash income. Agriculture's cash income in the United States in 1940 was $9,120,000,000. In 1920 it was $12,553,000,000, the greatest in American history. In 1932 it was $4,606,000,000, the lowest in the last 40 years. The national income in 1929 stood at the all-time peak of $82,885,000,000. In tabulated form the national income and that of agriculture (including government payments in the last 8 years) is as follows:

Year	*National income*	*Cash farm income*	*Government payments to agriculture*
1933	$42,430,000,000	$5,379,000,000	$131,000,000
1934	50,347,000,000	6,585,000,000	447,000,000
1935	55,870,000,000	7,378,000,000	573,000,000
1936	65,165,000,000	8,499,293,000	287,252,000
1937	71,172,000,000	9,111,024,000	366,899,000
1938	63,610,000,000	8,071,934,000	482,221,000
1939	69,378,000,000	8,541,582,000	807,065,000
1940	74,800,000,000	8,328,000,000	792,000,000

Cash income by commodities. A number of livestock and agricultural commodities produced and marketed in the United States are in the category of billion-dollar industries annually. These and other farm commodities are named and the cash income which they produced in 1936, 1937, 1938, and 1939 are given on the two following pages.

Increased farm income as a goal. "We must insist," says the head of the National Grange, "on greater farm income, the American price for the products used in this country, and a broad program to reach foreign markets." Approximately 60,000,000 of the 131,669,275 inhabitants of the United States, in 1940, were living in rural America. In that year, the nation had 6.812,000 farms and a farm population of 32,059,000. Farmers are far less than 50 per cent nationally organized. Members of the three national farm organizations total 1,343,850. Labor unions in the United States have nearly 8,000,000 members.

A national farm-organization official says that labor constitutes 65 per cent of the nation's population, is 75 per cent organized, and gets 67 per cent of the national income; that industry constitutes 10 per cent of the population, is 85 per cent organized, and gets 21 per cent of the national income; and that agriculture constitutes 25 per cent of the population, is 30 per cent nationally organized, and receives 12 per cent of the national income.

Commodity	Cash income			
	1936	1937	1938[1]	1939[1]
Crops:	1,000 dol.	1,000 dol.	1,000 dol.	1,000 dol.
Corn	264,918	224,316	269,395	326,039
Wheat	450,859	604,640	396,082	396,677
Oats	47,333	67,022	42,522	44,516
Barley	45,595	42,672	38,165	37,397
Rye	15,196	19,856	8,325	8,700
Buckwheat	1,837	1,952	1,519	1,371
Flaxseed	10,397	13,062	12,164	24,463
Rice	31,556	32,597	33,977	32,848
Grain sorghums	7,628	8,332	7,499	5,514
Cotton lint	763,360	770,377	562,131	525,320
Cottonseed	141,519	113,399	84,790	83,485
Tobacco	243,169	32,518	294,333	263,979
Dry edible beans	42,909	48,426	37,529	36,773
Potatoes	229,820	183,736	127,701	157,059
Sweet potatoes	22,816	24,391	21,792	21,350
Truck crops[2]	358,261	388,631	345,673	367,282
Citrus fruits	126,628	147,705	101,044	99,600
Apples	95,444	110,481	82,980	97,760
Peaches	40,014	50,330	31,169	40,572
Pears	18,803	16,875	12,630	15,437
Cherries	7,529	12,405	7,056	9,080
Grapes	39,043	54,638	37,828	37,785
Strawberries	34,902	42,604	37,509	39,158
Cranberries	6,848	7,561	5,226	6,909
Tree nuts[3]	16,224	21,144	18,506	18,930
Small fruits[4]	10,777	13,630	10,618	11,094
Other fruits[5]	38,054	41,850	31,097	36,731
Sugarcane for sugar	19,952	17,444	18,181	16,511
Sugar beets	55,675	51,836	54,598	50,481
Sugarcane sirup	5,940	6,571	5,926	6,497
Sorgo sirup	3,793	3,857	3,589	3,393
Maple sugar and sirup	3,280	3,923	4,370	4,104
Hay	85,729	95,992	67,117	65,400
Clover seed (red and alsike)	12,319	10,884	12,642	15,069
Sweetclover seed	2,143	2,159	1,288	2,028
Lespedeza seed	2,785	3,963	5,204	5,623
Alfalfa seed	8,804	12,156	9,931	11,983
Timothy seed	2,549	2,707	1,759	1,970
Soybeans	28,745	30,753	32,313	49,651
Cowpeas	4,736	5,826	6,147	5,729

[1] Preliminary.

[2] Includes all vegetables except dry edible beans, potatoes, and sweet-potatoes grown on commercial farms, and miscellaneous crops grown in garden plots not reported separately in census enumerations.

[3] Includes almonds, filberts, pecans, and Persian (English) walnuts.

[4] Includes blackberries, blueberries, currants, dewberries, gooseberries, loganberries, raspberries, and other berries exclusive of cranberries and strawberries

[5] Includes apricots, avocados, dates, figs, nectarines, olives, persimmons, pineapples, plums, pomegranates, prickly pears, prunes, and quinces, as well as cherries in noncommercial States.

Commodity	*Cash income*			
	1936	*1937*	*1938*[1]	*1939*[1]
Crops:	*1,000 dol.*	*1,000 dol.*	*1,000 dol.*	*1,000 dol.*
Peanuts	35,135	38,207	45,257	34,086
Hops	6,942	6,411	6,340	8,773
Other[6]	185,146	201,948	192,302	210,869
Total crops	3,575,112	3,877,787	3,126,224	3,237,996
Livestock and livestock products:				
Cattle and calves	1,097,767	1,214,699	1,143,986	1,274,714
Hogs	964,682	923,252	868,535	821,097
Sheep and lambs	170,391	191,966	162,070	180,265
Poultry[7]	317,414	305,051	287,958	295,278
Eggs (chicken)	466,420	512,561	473,313	422,937
Milk	1,459,182	1,531,510	1,396,118	1,355,067
Wool	96,824	117,270	71,239	84,324
Other[8]	64,246	70,029	60,270	60,859
Total livestock	4,636,929	4,866,338	4,463,489	4,494,541
Total crops and livestock	8,212,041	8,744,125	7,589,713	7,732,537
Government payments[9]	287,252	366,899	482,221	807,065
Grand total	8,499,293	9,111,024	8,071,934	8,539,602

[6] Includes broomcorn, field peas, popcorn, peppermint, sweet sorghum for forage, and forest, nursery, and greenhouse products.
[7] Includes chickens and turkeys.
[8] Includes horses, mules, ducks, geese, mohair, and honey.
[9] Includes agricultural conservation, Sugar Act, rental and benefit, and cotton option and price adjustment payments to farmers.

Group coöperation suggested. According to Colorado's State Grange Master, speaking in December, 1940:

> Farmers have left the days of purely individualistic efforts. They will attempt to work out their problems through cooperation with labor, manufacturers, general industry and business groups.

Groups of the public, particularly in the last 40 years, have increasingly demanded more extensive and more diversified services from the Government. Science has enormously enlarged the capacity and consequences of action by groups. Dr. J. D. Black, Harvard professor, speaking before the American Farm Bureau Federation's convention at Baltimore, Maryland, in December, 1940, said:

> Farm organizations of the United States, though they did not help write the treaty of Versailles, were as much responsible as any other one group for the mistakes in national policy and programs made by this country from 1920 on. This time they may be responsible even for the mistakes made in the new peace treaties that are written; and they will be highly responsible for the conduct of our public affairs afterward.

Farm-organization attitudes. Although the three national farm organizations envision the continuation of the current national farm pro-

gram, the National Grange does not accept it as "a real farm program," the Farmers' Union regards it as "a weak substitute for effective help to agriculture," and the American Farm Bureau Federation considers it "fundamentally sound." Some changes in the program and its administration have been proposed by each organization.

Continued Federal aid to agriculture was favored by all three organizations at their respective annual meetings late in 1940. In substantial agreement on some issues and policies, they contend that: (1) farm income in 1940, despite Federal aid to agriculture, was still considerably below the total which they regard as an "adequate share of the national income"; (2) the present war has practically completed the destruction of foreign markets for American crops produced for export; (3) the temporary prosperity of industry, resulting from the national-defense program, is reflected to a greater extent in prospective increased prices for things that farmers buy than for things that farmers sell; and (4) benefits to agriculture from industrial activity and increased payrolls will apply to farm products that are domestically consumed, while American export farm products, already depressed, will suffer still more as a result of vanishing or closed foreign outlets.

According to the Ohio Farm Bureau Federation (January, 1941), comprising Ohio county farm bureaus:

> We have 29 per cent better than parity on the things we have bought cooperatively in large volume. When we do the same good job through organization and user cooperation on all the other things we buy, there will be no farm problem.

Major things that Ohio farmers do not buy coöperatively are listed as home- and farm-building materials, farm machinery, store-bought food, furniture, furnishings, and family clothing.

American democracy challenged. It is increasingly realized that, in the long run, the farm problem will have to be solved, not on the farm alone, but in the general industrial and economic system whose defects have created the problem. Secretary of Agriculture Claude R. Wickard, in an address at Syracuse, New York, November 15, 1940, said:

> Our democracy, if it is to be strong and unassailable, must give serious and continuous attention to bettering the lot of low-income groups in cities and on farms. Raise their incomes and you raise their buying power. Raise their buying power and you create new markets for the production of our machine industry and increasingly mechanized agriculture. That seems to be about the only place we can look for new markets in the world as it is today.

The United States Department of Agriculture

Information and research foremost. Charged with acquiring and diffusing among the people of the United States useful information on subjects connected with agriculture, the Department of Agriculture also conducts research and extension work. Back of every activity of the Department there is a research problem, scientific or economic. More

than 7,000 members of the Department's personnel are technical workers. Functions of the Department relate, not only to research, but to education, conservation, marketing, crop and livestock improvement, production and manufacture of dairy products, home economics, and conservation. Research results are made available by the Department for practical application through extension and experiment-station work in coöperation with the states.

The Department provides crop reports, commodity standards, and other marketing services, and Federal meat-inspection service. It works to eradicate and control plant and animal diseases and pests; administers more than 50 regulatory laws designed to protect farmers and the general public; enforces the Sugar Act of 1937 and the Commodity Exchange Act; promotes the proper use of soil and forest resources; provides rural rehabilitation; administers the ever-normal-granary program through commodity loans and marketing quotas; provides agricultural credit; assists tenants to become farm-owners; facilitates the introduction of electric service to persons in rural areas; insures wheat crops against natural hazards; and diverts price-depressing surpluses to exports, new uses, and relief.

Coördination of activities. The Department is composed of 25 bureaus, divisions, offices, or units, and carries out the provisions of 300 acts of Congress. A broad new function of the Department is to act as a board of strategy, a general staff of specialists in the Bureau of Agricultural Economics and the Agricultural Planning Board, which is an over-all planning agency. Planning techniques of the Department are developed democratically by free discussion in groups composed of scientific specialists, Federal and state officials, and the farmers themselves. A scientifically developed program requires, first, that a hypothetical plan be arrived at by Department specialists; second, that there be a thorough discussion of the plan, with alterations and revisions in the light of the discussion; third, that the plan be tried out, as it is often found wanting as new facts appear; fourth, that the plan be once more revised and tried in its new form; and fifth, that the plan be then placed in action.

The Department recognizes that coördination must reach into all aspects of its work. In large-scale group activity, public or private—including industry, agriculture, finance, and everything else—five steps are involved in research, planning, and administration. Finally, the over-all job is to coördinate these three and see to it that each one is genuinely related to the others. During 1939, farm men and women, numbering 70,000, organized themselves into community and county planning committees. In 1,195 counties in 47 states, they sat down with representatives of Federal, state, and local agencies to develop plans, policies, and programs for their counties. These committees planned for action by individuals, by groups, or by public agencies.

Duplication and conflict among the various programs and activities of the Department are not important administrative problems; the hard and complex job is to adapt national farm programs to the special needs

of particular areas under widely varying conditions. Through coördinating its work, the Department is moving toward the goal of adapting national programs to the specific needs of all the states, agricultural counties, communities, and individual farms.

Brief reviews of the work of a few of the Department's newer agencies are given elsewhere in this chapter.

Soil Conservation as a National Policy

Science and machinery as aids. Machinery and modern farming methods have provided the means by which farmers on fair-to-good land may decrease the available fertility of soils more rapidly and on a greater scale than were possible in practical agriculture 40 years ago. At the same time, however, thanks to science and machinery, most farmers can do much to increase the fertility of their crop and grass land at a more rapid rate than was possible in 1900. To increase the organic matter or humus in abused and eroded soils is a much slower but necessary job for millions of farm families who are farming these soils.

Soil erosion and soil depletion represented a dangerous, widespread trend that had begun in the last half of the nineteenth century and was growing rapidly after 1914. By working together since 1933 under national programs for soil conservation, farmers have made substantial progress in altering the trend.

Yearly cost of erosion. In his 1940 report, the chief of the Soil Conservation Service stated that erosion of the soil costs the United States about $3,844,000,000 a year. It is a threat to the productive capacity of the nation, a drain on the country's agricultural resources, a cause of rural impoverishment, and a dangerous fissure in the preparedness dam we are building against unfriendly tides in other continents. Across the country we have permitted the essential ruin of 282,000,000 acres of crops and grazing land, and have allowed the process of erosion to get under way on 775,000,000 more acres of all types of land. Half of the land of the country has been damaged by erosion. "We can conserve our soil. We know how to do it. We can, if we will, make it produce abundantly, and without waste, for any and every production need that may face us," says the report.

On March 15, 1941, as this chapter ends in an atmosphere tense with the din of national-defense activities, it seems probable that the state of international trade after world peace shall have been established will require changes in American agricultural adjustments. It is more than probable that soil, timber, water, and grass conservation will continue under a national policy and program for agriculture. For the idea of conserving basic natural resources as an essential, permanent social job has been accepted by the American people. They realize that, upon the deepening success of this primary contribution to national defense, depends their future well-being and security in a world in which rapid changes are forcing the peoples of the Western Hemisphere into neighborly coöperation with one another.

3

The Meat-Packing Industry

Early History of Meat

Although most of the development of the present meat-packing industry has occurred since 1800, or even since the Civil War, the story of livestock and meat is as old as man. It is carved on the walls of caves that sheltered the prehistoric cave dwellers of middle Europe. Patriarchs of Biblical times knew it well, because they prospered only as their herds of cattle and sheep prospered. Mighty kings of Assyria and Egypt decreed that the slaughtering of animals for food should be performed only by the priests. During the reign of the Ptolemies, stringent food laws covering the preparation of meat for consumption were rigidly enforced. In the Middle Ages, powerful butcher guilds were organized in most of the large cities of Europe and, for centuries, represented a significant influence in the life of a community. The Worshipful Company of Butchers, of London, England, was founded in 1180 and continued to be a power for several centuries. Statutes on the "profession of butchering" were made in France in the middle of the same century.

For many centuries, the people of every town and village were dependent upon local livestock production for their meat supply. In many European countries, this condition still exists. It was in America that the packing industry grew to its present size and significance.

Of deep importance to the growth of every large industry was the industrial revolution of the nineteenth century. During the early part of this century, the extraordinary expansion in the use of machinery in Europe and in America and the improved means of transportation gave commerce an unprecedented stimulus, which resulted in the development of industrial centers of large population. As these cities increased in population, there grew up a huge demand for meats—a demand that has gone on increasing in volume until, in recent years, it has become the largest in history. It was this demand that created the impetus for the organization of the meat-packing industry on a substantial scale.

reported that "in the twenty leagues they had been over they had seen nothing but cows and the sky."

Incidentally, Texan history may be of interest, in view of the fact that Texas now often boasts nearly twice as many cattle as any other state Texas was first traversed by four survivors of the ill-fated Narváez voyage to Florida (1528). These men—three whites and one Negro—spent most of their 8 years of wandering in hunger, nakedness, and recurring slavery and escape among successive Texas tribes of Indians. Their leader was rather prophetically named *Cabeza de Vaca,* Mr. Head of a Cow.

The wild horses that once ranged the American plains were descended from the horses that strayed from the Coronado and other Spanish expeditions from Mexico northward during the sixteenth and seventeenth centuries. The horse, incidentally, transformed the American Indian, once a slow footman who probably thought at first, like the Aztec adversaries of Cortez, that man and horse were the same animal, or, like the neighbors of the New Mexican cities conquered by Coronado, that these fierce people were mounted on animals that ate human beings. It has been pointed out that the horse probably wrought as great a change in the life of the Indian as did the locomotive in that of the white man.

Stock Raising in the Colonies

Although some cattle reached Virginia prior to 1609, the first large shipment was in 1610. The first sheep were brought from England to Jamestown, Virginia, in 1609. In 1624, Governor Edward Winslow imported a number of cattle at Plymouth, Massachusetts, but for years they were so rare that six owners were required for every cow.

So vital was meat food to those early settlers that, in order that valuable animals transported so carefully overseas should be kept to breed and multiply, an edict was published forbidding the killing of domestic animals of any kind. The penalties were severe in the extreme: death to the principal, burning of the hand and loss of the ears to the accessory, and a 24-hour whipping to the concealer. Those were harsh measures even for the beginning of the seventeenth century, but an adequate supply of meat was a life-and-death matter for the early colonists.

During colonial days, dairying, cattle feeding, and hog raising were carried on together. By the middle of the seventeenth century, an important cattle industry had developed in the Connecticut River Valley. From the pastures of New Hampshire and Vermont, large droves were annually driven south to be sold at Boston or to feeders and dairymen in the three southern New England states. By about 1772, settlers from Virginia and Pennsylvania had reached the Monongahela Valley, where herds of 400 or 500 head were soon common.

Beginning of the Meat-Packing Industry

The conditions that gave rise to the present organization of the packing industry originated when settlers in the Ohio and Mississippi Valleys

began to raise livestock. As Eastern cities grew, livestock production on the Atlantic Seaboard could not keep pace. Supplies had to be brought from points farther and farther away.

At first, livestock from more distant localities had to be driven across the country. Then, with the advent of railroads, the animals were shipped alive in stock cars. During the middle of the past century, the traffic in live animals to the Atlantic Seaboard became important. The first step in moving the industry to the source of raw materials was the development of pork packing in cities west of the Alleghenies. Cincinnati became the first important pork-packing center in the country. In those days—before, during, and shortly after the Civil War—the shipment of meat products over long distances was confined entirely to cured products and principally to pork products. Pork was salted down and packed in barrels, and thus arose the name "packing industry." This name is more or less a misnomer today, for it is really much more applicable to industries like fruit and vegetable canning, where packing in containers is an important feature. This packing or salting down of meat for shipment to distant points was practiced as early as 1640, when New England farmers took advantage of the Cromwellian wars in England to sieze the salt-pork trade of the West Indies. The first American meat packer whose name is known was Captain John Pynchon, a storekeeper, miller, fur trader, Indian-war commander, and judge in Springfield, Massachusetts. He was the son of the city's founder, William Pynchon, the first American now known to have been a meat retailer. Between 1645 and 1662, the two, in turn, bought venison from the Indians for retail sale. The son was shipping cattle to Boston by 1655, and buying and barreling pork by 1662.

Advent of the refrigerator car. The great drawback to the development of the packing industry in the Middle West was the impossibility of shipping fresh meats for considerable distances. It naturally followed that attempts were made to solve this problem, and from these attempts, came the refrigerator car. The first successful experiments were made about 1870, and the result was the rapid development of meat-packing companies in Chicago and other Middle Western cities. Modern refrigeration made possible a regular flow of fresh meat every day from all producing countries to every consuming center on the globe. As Dr. Mary E. Pennington has summarized the subject: "The people of the United States are as dependent upon refrigerator cars for their food supply as the people of England upon ships." The discovery of antiseptic surgery was not more epoch-making than was the solving of the problem of cold transportation for foods.

Obstacles tending to retard progress. At first, there was a decided prejudice against Western meats in Eastern markets. There were other obstacles, such as the opposition of the railroads—for they had equipment of livestock, not refrigerator, cars—of Eastern stockyard interests, and of other industries that had grown up from the feeding and shipment of Western animals by rail to Eastern markets. The opposition on the part of the railroads was so keen that the Chicago packing companies had

to provide their own refrigerator cars. A number of the packing companies still continue to operate their own equipment and, as a result, they have developed transportation departments that are responsible for keeping track of the refrigeration cars, repairing them, and giving the expert service they require. The meat companies pay the railroads the regular freight rates on the products shipped, and they receive a mileage rental from the railroad companies for the use of the cars. During some periods, this mileage rental has yielded a small profit to the packers from the operation of refrigerator cars; at other times, it has resulted in a loss. This whole situation is now under the control of the Interstate Commerce Commission, and mileage rentals are adjusted from time to time in accordance with the cost of maintaining and operating the cars.

Concentration of the industry in the Middle West. After the obstacles mentioned in the foregoing paragraph were overcome, the industry, centering in Chicago, began to grow rapidly. It was inevitable that it should develop, but its establishment was greatly hastened by the fact that certain men of unusual ability entered the field. Livestock production spread to the Northwest, the West, and the Southwest, and consequently additional packing centers grew up—such as those at St. Paul, Omaha, Sioux City, St. Louis, Kansas City, Denver, Oklahoma City, and Fort Worth. Packing houses cannot always be distributed freely throughout the producing fields, because if their numbers were too large, the individual packing house would be too small for economical operation and the livestock supply and shipping facilities would be inadequate. In the location of packing houses, there is an economical balance between producing areas and consuming sections.

Size of the Meat-Packing Industry

The American meat-packing industry is one of the world's largest industries. According to figures issued by the Bureau of the Census of the United States Department of Commerce, the meat-packing industry, as measured by the value of its products, usually ranks from first to third among the industries of the United States.

The latest figures available, those for 1939, show that the plant value of packers' products amounted to $2,648,325,552, as compared with $4,039,930,733 for the automobile industry and $2,720,019,564 for the steel industry. The number of establishments listed in 1939 was 1,478. The industry employed an average of 119,853 individuals and paid them slightly more than $161,500,000.[1] On each business day, packers paid out for livestock and other materials an average of more than $7,000,000.

Fresh meat produced, according to the Census report, represented a little more than half the total product value. Cured meats (which include hams, bacon, and corned beef) represented approximately 17 per cent of the total value. Another 5 per cent of the total was sausage, headcheese, etc., and more than 2 per cent was canned meats, including

[1] Figures do not include administrative employees.

canned sausage. More than 1,500,000,000 pounds of lard were produced, with a value of approximately $107,000,000.

Hides, skins, and pelts had a total value of about $94,500,000, while the wool produced was valued at $16,700,000 and hair at about $1,300,000. Other by-products were valued at about $220,000,000.

Economic Significance of the Industry

The production and consumption of meat have a significance that extends far beyond the livestock and meat industry. Livestock consume a large part of the grain, hay, and other roughage produced on the farms, and thus transform into nutritious human food much material that would otherwise be wasted. At the same time, livestock provides fertilizer for the enrichment of the soil. The consumption of farm products by livestock not only constitutes one of the fundamentals of economical meat production but forms the basis of any permanent system of agriculture. The importance to the nation of this side of livestock production is pointed out by Dr. John R. Mohler, chief of the Bureau of Animal Industry of the United States Department of Agriculture:

> One may ask why it is necessary or even desirable to have a large animal population in a country such as this, with its millions of automobiles and trucks and its vast acres for producing cereal grains. The answer is simple. Our domestic animals, developed through long years of evolution, are marvelously efficient in converting vast quantities of grasses, forage, plants, and other products which are of slight direct value to mankind, into available animal products. These products include meats, milk, butter, cheese, leather, fats, wool, mohair, and almost countless by-products, ranging from violin strings to fertilizer.

Dr. Mohler further mentions:

> The United States contains the largest corn-producing region in the world, yet the human population uses only about one-tenth of that crop directly as food. The public appetite much prefers to use the corn crop in the form of juicy steaks and savory hams. Through the stockmen's skill our domestic animals are becoming gradually more efficient in converting coarse feed into refined and concentrated products. As alchemists for the refinement of base materials, cattle, swine, and sheep —to say nothing of goats—have an enviable record.

Reasons for Present Geographical Location of Industry

The location of any industry is seldom definitely fixed; usually it changes with the evolution of the country. The meat-packing industry, along with others, has gone and is going through a process of evolution in response to changing economic and geographical forces. The modern packing industry made Cincinnati famous, with the nickname "Porkopolis," in the first half of the nineteenth century. Chicago, in turn, took the lead under the impetus of Civil War demands.

The locations of individual packing plants depend upon a great many -erent factors. From an economic standpoint, the most important ones

are livestock supply, labor supply, shipping facilities, distance from markets, and competition.

From the standpoint of livestock supply, the planning of a location for the packing plant depends upon present supply of livestock, tendencies in livestock production, receipts at the market where purchases will be made, and methods of assembling livestock. These factors may explain in part the reason for the present concentration of the industry in the Middle West.

Raising Livestock for Market

Large numbers of calves are bred every year under what is called the "extensive system" of farming on Far Western range lands. There they remain steadily growing on the native grass, perhaps until they are 1½ or 2 years old. They are then loaded into railway cars for shipment to some Midwestern stockyard to be offered for sale to another farmer, who will fatten, or "finish," them for the packer. En route, they are under careful supervision against ill-treatment by overcrowding, trampling, or accident. It is one of the laws of the land that cattle passing from one state to another shall not generally be left for more than 28 hours without being taken out for feed, water, and exercise.

On arrival at the stockyards, the steers are placed, possibly with thousands of others, in pens for inspection by buyers of feeder stock. These, under our modern, specialized methods, are usually commission men, or agents, who make the purchase and sale of livestock their sole business. They are so named because they carry out sales and purchases for farmers and others, and take a commission of so much per head of the returns.

The agent may have received an order to buy a "couple of carlots" of young, unfinished steers for some Midwestern farmer who makes a business of feeding these to market weight and condition. This process may take several months in the "feed lots." When the animals have almost reached the required weight, they are "finished" for market on a ration that generally consists of corn and other concentrates, and calls for special skill on the part of the feeder.

Then the steers, each weighing several hundred pounds more than when it entered the lot, are again shipped to the stockyard for resale, this time to the buyer for a packing house, and are finally driven to the adjacent plant for slaughter and conversion into usable beef for our tables.

Calves also are produced on farms in the corn belt and other districts, as well as in the range regions.

Methods of Marketing Livestock

There are two main ways in which farmers market their livestock. The first is through the public livestock markets located at various points throughout the country—such as Chicago, St. Louis, St. Joseph, Kansas City, Omaha, Sioux City, St. Paul, and about 60 others.

The second way of marketing livestock, commonly known as "direct

selling," is for the producer or shipper to sell it direct to a packer. The price is based on the price for comparable grades of livestock at some public market, usually in that territory, with an allowance made for freight from the buying point to the city or town in which the basic central market is located. Government figures on purchases of livestock include those dressed by all plants under Federal inspection and by some of the others; they indicate that about half the hogs marketed commercially, and about a third of the calves, sheep, and lambs, but less than a fourth of the cattle, are now sold direct

Fig. 1. Buying lambs.

Operation of the Stockyards

The stockyard company owns the yards along with all the necessary equipment for unloading and sheltering the incoming livestock. It also has vast facilities for taking care of the transient livestock, feeding and watering them, and disinfecting the pens. The income of the stockyard company is derived from charging the shipper a small yardage fee and from the sale of feed for the livestock. The function of the stockyard is to provide a central housing location for the concentration of livestock where commission-house salesmen and packing-house buyers can assemble for the purpose of selling and buying the animals.

As a rule, the farmer who raises livestock and ships it to market receives cash for his shipment almost as soon as it is physically possible for the money to reach him, for the packer pays in cash or its equivalent for every purchase. When a carload of livestock reaches the stockyards

it is unloaded into the pens and the animals are fed and watered. The commission firm to which the shipment was consigned by the farmer then undertakes the sale of the animals to a packer. The packers' buyers ride through the stockyards and make bids, and finally the commission men sell the animals to the highest bidder.

The animals are then weighed by stockyard officials and are driven to the packers' pens, where they rest until they are needed for processing. Owing to physical differences between the different kinds of livestock, the processing methods vary. Inasmuch as the small-stock (calves, sheep, and lambs) operations are fairly similar to those used for cattle, descriptions of hog and cattle operations alone will suffice to give an idea of the methods used in the modern packing house.

Processing Hogs

When the hogs are thoroughly rested, they are driven in small batches to the top story of the packing house. There they are swiftly dispatched and are then dropped into a scalding vat, which loosens the hair and the surface of the skin. The next step takes the hog to the scraping machine, where the hair is almost completely removed by flexible beaters that carry dull, steel knives. This ingenious device even removes most of the hair from the heads and feet.

In order to complete the removal of the hair, particularly the fine hairs, according to a practice now becoming prevalent, the hog is momentarily immersed in a melted mixture of rosin and oil. After removal of the hog from immersion in this mixture, the coating of rosin and oil is hardened by spraying with cold water. The coating is then pulled off, and with it come the imbedded hairs and hair rootlets. In addition to removal of the hairs, the application of this coating has a cleansing and sterilizing effect on the surface of the hog carcass.

From this machine, the hog goes upon a moving table where workmen continue the cleaning process. At this point, a short, thick stick, known as a "gambrel," is inserted between the hind legs under the tendons. The gambrel is hooked in the middle to an overhead trolley, and the hog is raised from the table, hanging head downward. The trolley then moves along an overhead rail, with a hog spaced every 2 or 3 feet along the rail. Thus the animal is conveyed at a certain speed past a series of workmen. The movement is timed to allow each workman to perform a certain operation on each hog as it passes him. The meat-packing industry was the first to adopt this ingenious plan of taking the work to the man instead of making the man move about to perform the task—a practice that has revolutionized American industry generally and helped to make it the foremost in the world.

The first operation, as the hog moves down the rail, is the further cleaning of the carcass, which is done first by men with long sharp knives and then by means of showers of water under high pressure.

After cleaning, the head is removed and then the intestines, or viscera. These parts are examined immediately by inspectors, so that any traces

of disease may be detected. (The inspection service is described later in the chapter.) The pulling of the leaf fat and the splitting of the carcass through the middle of the backbone follow next in order. After a final washing, the carcass is sent into the coolers, where it is chilled and held for cutting into the parts required by the trade.

Cutting the Meat

Great skill is required in every cutting operation, because the value of the meat depends to a great extent on the appearance and shape of the cuts. One wrongly directed knife cut may greatly lower the sales value of a ham or a loin. The method of cutting, moreover, varies from time to time, depending upon market conditions. These changing conditions require skill on the part of the management as well as the workman.

The principle of carrying the work to the workman is used again in the cutting operations. The side of the hog is placed upon a moving table, where the ham is sawed and cut off. At the end of the table, the shoulder is chopped by means of a cleaver or an automatic chopper. The shoulder goes in one direction on a conveyor, the middle in another. The shoulder is then trimmed and cut up into retail meat cuts.

In the meantime, the hog middle is sent to a group of workers who cut and "pull" the loin and remove the spareribs. The remainder, which now is boneless, then is flattened by running between two rollers to permit proper trimming. The upper portion, or fat back, next is cut away by means of a knife.

The cuts which are to be shipped in fresh form, such as the shoulder cuts, loin, and spareribs, are immediately packed into containers and made ready for shipment to branch houses or retailers. The other principal parts which are to be cured, such as the ham, belly, fat back, and certain of the shoulder cuts, are sent to the curing rooms below. These cuts are then inspected, trimmed, and prepared for curing.

Methods of Curing Meat

In general, there are four methods of curing followed today. The first is the sweet-pickle process, in which the meat is placed in large watertight vats, together with a mixture composed of salt brine, sugar or some similar sweetening agent, and a small quantity of nitrate (or nitrite) of soda. The curing room must be held at a steady temperature between 36 and 40 degrees F. This cure is applied mostly to hams, picnics (cuts from the shoulder), and medium weights of bellies. The cure requires from 15 to 45 days, depending upon the nature and weight of the cut and the strength of cure desired.

The second process is the dry-salt method, which is used for some of the heavier cuts of meat. It consists of rubbing salt on the surface of the meat and stacking with salt between the layers, around the edges, and on top.

The third method is the so-called "dry" cure, which is used mostly for

fancy bacon and other cuts requiring a mild cure. The meat is packed very tightly into watertight containers with a slight sprinkle of salt, sugar, and nitrate of soda between the layers. In this method, the meat cures in its own juices.

In recent years, there has been quite a development of the so-called "arterial" method of curing. The curing ingredients are introduced in solution form into the arterial system of hams and shoulders. The cure is forced in under pressure through a hollow needle inserted in the exposed ends of the arteries The cuts are then submerged in a cover pickle. The time required for the cure to be effected is very greatly reduced in this way, because it is not necessary to wait for the cure to diffuse from the outside to the center of the cuts.

The salt is used to preserve the meat and prevent spoilage. The sugar neutralizes the flavor of the salt. The nitrate of soda serves to maintain the attractive color of the meat and may have an additional preservative function.

Smoking meat. Smoking, the sequel to the cure, is the next step. The smoke from burning hardwood adds greatly, not only to the flavor of the meat, but also to its appetite appeal, for it causes a delicious brown color in the meat and enhances its keeping qualities. Probably 80 per cent of the pork cured is smoked.

Manufacturing Lard

Lard making is another important packing-house operation. Lard is made from hog fat The leaf fat makes the finest grades. There are a number of methods of rendering lard, the open-kettle and steam-pressure methods being the most common. The purpose of the rendering is to remove the fats from the meat fibers and to change the consistency of the fats. The process consists of cooking, filtering, and chilling.

The by-products from rendering are cracklings and tankage, which are valuable as stock and poultry feeds.

Processing Cattle

The cattle are driven to the top floor of the plant and then into narrow pens, where they are stunned with a blow from a heavy hammer. They are then hoisted into the air by the hind legs for sticking. Following the sticking, the heads are removed and washed for inspection. The carcasses and the parts from each animal are kept in the same order throughout the processing until the inspection is completed.

After the removal of the heads, the animals are dropped to the floor; the legs are detached at the knee joints, and the hide is removed from the sides, after being slit down the center of the belly. The next step consists of raising the animal from the floor and removing the viscera, which are placed in a receptacle for inspection by Government inspectors.

The hide is then removed from the rump, and the carcass is raised clear of the floor. The next step is the complete removal of the hide. This

operation is followed by sawing the aitch bone and splitting the carcass through the center of the back down to the neck with a long cleaver. The split carcass is conveyed on a moving trolley for thorough washing and further inspection. The entire processing requires little more than 1 hour. After it is completed, the carcass is sent to the cooler, where it is chilled for from 24 to 36 hours.

Beef is delivered to retailers either in whole sides or quarters (half sides), or, in some cases, in wholesale cuts. Beef sides and cuts are protected by cheesecloth wrappers and burlap.

Meat Inspection

The inspection of meat is an important part of the packing-house procedure. In the case of packers doing an interstate business, the inspection is made by Government inspectors under the supervision of the Bureau of Animal Industry of the United States Department of Agriculture. These inspectors are trained men, and their inspection, which takes place both before and after slaughter, is very thorough. When all parts of a meat animal have passed inspection, a small purple stamp, colored with vegetable ink is applied to a number of places on the animals. This stamp consists of a circle in which appears the legend "U. S. Insp'd & Passed" and the official number assigned by the Government to that plant. So thorough is this inspection that many foreign countries admit American meats to their ports without further local inspection if they already have been approved by the United States Government.

This Federal Government inspection service is conducted only in the plants engaging in interstate commerce, which handle about two thirds of the total meat supply. Meat processed by other packers is frequently inspected by state, municipal, or private inspectors, whose standards often are the same as those of the Government men.

By-Products

By-products represent one of the most noteworthy, if not epoch-making, developments of the packing industry. In general, a by-product may be defined as anything from a hog, steer, or sheep that is not considered as meat proper.

Coincidental with the building of central packing plants arose the necessity of disposing of the waste materials, or offal, which make up about a quarter of the live weight of a meat animal. In the old butchering days, these materials were thrown away and wasted, because their value was not understood and because no means existed to turn them to account. Today, they are taken either by packers or by specialized traders who have sprung up because of the raw material made available by recovery from packing-plant operations. A few of the more important products made from recovered materials are: glue, soap, oleo oil (which gives its name to oleomargarine), stearin, casings (for sausage), and gut for musical instruments and tennis racquets (from sheep intestines).

Fig. 2. Stamping and branding beef.

Leather from the hides has a record going back to high antiquity. Other fairly well-known by-products are the horns and hoofs, which, after softening by the action of steam, are laminated or split to make combs, brush handles, and similar articles. Bones are used for knife handles, knick-knacks, and dice. Blood is utilized in some cases to furnish albumen, but usually, along with the odds and ends of meat, fat, and residue that cannot otherwise be turned to account, it is made into fertilizer.

Humanitarian by-products. It is in the field of the pharmacist that the rather prosaic by-product finds its most surprising applications. Pepsin is one of the most widely used bases of remedies for dyspepsia. Surgeons now use ligatures made of sheep intestines for sewing wounds. In some surgical operations, a substance that comes from the adrenal gland near the kidneys is employed to prevent hemorrhage. Kephalin also is used, because it clots blood and acts as an astringent. A third substance, lecithin, is used to counteract snake poison and the venomous sting of insects. Other materials obtained from the brains of cattle for use in medicine and surgery are the pituitary and pineal substances. Pancreatin is a digestive ferment; insulin, recently discovered for the relief of diabetes, is obtained by a distillation process from the pancreas; from the thyroid glands of sheep, preparations are made that are prescribed in cases of premature bone hardening. Several other medicinal preparations are made today from what were formerly wasted portions of meat animals. In all, it has been estimated that about 140 articles which may be classed as by-products are now obtained from meat animals.

The economics of by-products. One could scarcely conceive of the packing industry without its by-products. Because of the inclusion of by-products in the value of the meat animal when bought, the packer can and does pay a higher price for it to the farmer-producer. The saving made possible by by-product values may also affect the price of meat in some situations.

Storing Meat

Seasons, weather, prices, and other factors affect the production and marketing of livestock and cause variations in the quantity marketed. Hence, the supply of meat is likely to be greater in certain months than in others, whereas the demand from consumers is fairly even, except as consumer income in the aggregate varies. By storing surplus products under refrigeration in fresh, frozen, or cured form, the packer is able to hold the surplus for later periods when the supply of livestock coming to market will be too small to meet the consuming demand.

A period of storage is also necessary because of the time required for the curing and smoking of meats. This period varies roughly from 15 to 45 days, depending on the cut and the intensity of cure desired.

The greater part of the stocks in storage consists of pork products, and the supply on hand at any one time is rarely greater than a 3-week meat ration for the country. The storage period ordinarily does not exceed a few months.

Shipping Meat

Perhaps the cave man of prehistoric times preserved his foods in winter by natural frost, as Eskimos and Laplanders do today. A generation ago, the practice was wide-spread in the United States, and it still is prevalent in the North. Frozen-beef quarters and pork carcasses are still

kept in perfect condition for 5 months in a great part of Canada. It was only natural that early meat packers, handicapped by the perishability of their goods in warm weather and their inability to ship meat from regions of surplus supplies, should have turned to the use of artificial cold, or what we know now as "refrigeration," an art which has so advanced in the last 50 years that it is now a specialized branch of engineering.

Merchandising Meat

In most industries, when the primary manufacturing steps have been completed, the goods go forward into market without further effort on the part of the manufacturer or, at least, find sales channels in which he is only indirectly concerned. This is not true in meat packing. The actual distribution of the finished goods is carried out to a large extent by the primary manufacturer. The fact that the bulk of the supply of livestock in the United States is produced west of the Mississippi River and the bulk of the meat is consumed in the territory east of that river makes necessary a complicated and efficient system of distribution.

From packing plants, meat is distributed to all parts of the nation and of the world. This is accomplished through branch plants, branch houses, wholesale markets, and car and truck routes. Goods are sold, not directly to the consumer, but to retailers. Branch houses, which are sales agencies, ordinarily do only a limited amount of manufacturing, confining their operations largely to sausage making and to the smoking of hams and bacon.

Car routes are operated in regions where the trade cannot conveniently or adequately be supplied from a plant or from branch houses. Ordinarily, car-route orders are obtained by a salesman from dealers in a number of villages or cities in a given territory, after which the goods are packed in a refrigerator car for shipment. Careful attention is paid to placing the orders in such a way that they may be unloaded with maximum efficiency as the car goes from point to point. Motor-truck routes are handled similarly.

Many retailers obtain their meat supplies by truck from wholesale markets at plants or branch houses adjacent to their places of business. Others obtain their supplies by ordering by mail, telephone, or telegraph, or from a salesman from a plant or branch near by, or perhaps in some neighboring city, whence the order may be shipped by express or freight or delivered by truck. Some retailers, of course, conduct their own killing and dressing operations in a limited way and do not depend altogether on the packer for their meat supply.

The number of retailers who handle meat probably exceeds 225,000. A netlike, smoothly working delivery system brings meat into even those remote homes which formerly the village butcher himself did not reach. In the United States, few packers carry on a direct retailing business, but one of the largest English firms maintains a vast retail chain-store

system throughout Great Britain for meats prepared in its packing plants in Australia and Argentina. It will be noticed that the American system comes to within one step of the farmer-producer, on the one side, and, on the other side, to within one step of the consumer, thus making all but two of the links in meat supply from farm to table. The record of industrial economics has but few instances of single service quite comparable to that of the packing industry. Indeed, the efficiency of the American meat-packing industry is becoming proverbial.

Figures issued by the United States Bureau of the Census show that meat packers pay out for raw materials, chiefly livestock, usually about 85 per cent of the plant value of meat and by-products. All expenses of operation—including wages, freight, interest, depreciation charges, taxes, and so forth—as well as a small manufacturing profit come out of the remaining 15 cents of every dollar. Out of the money received from the packer for livestock, the producer must pay all the expenses of raising, breeding, feeding, and marketing the farm animals.

In a recent survey by the United States Department of Agriculture of margins, expenses, and profits in retail meat stores, it was found that, on the average, out of every dollar received from the sale to the consumer, the retail meat dealer pays out 77.6 cents to packer or wholesaler as the cost of meat and that the retail dealer's expenses average 19.5 cents out of each dollar of sales, leaving 2.9 cents for profit.

Meat-Export Trade

American meat has, from an early date, been exported in considerable quantities. In 1747, Charleston, South Carolina, reported the exportation of 3,114 barrels of pork and 1,764 barrels of beef. In 1790, the records of external trade show that 6,000,000 pounds of pork products were exported from the United States.

During the first third of the present century, American pork products were exported to nearly 50 countries, of which Great Britain, Germany, the Netherlands, Cuba, France, Belgium, Mexico, and Poland were the most important. Practically no beef, veal, or lamb were exported, however, except during and just after the First World War.

By 1939, meat exports from this country had become almost negligible, as a result of tariffs, quota systems, and other trade barriers. Lard exports also had dropped drastically.

Argentina, Australia, Canada, and New Zealand export relatively large quantities of meat. Most of their products go to Great Britain.

Export meats are transported in fresh, frozen, or cured form in refrigerated ships.

Methods of exporting. When exporting, American meat packers may sell in any of the following ways:

(1) Through their own branch houses.
(2) Through exclusive foreign agents.

(3) Through foreign agents who may handle products for a number of packers.
(4) Through coöperative export organizations.
(5) Through export brokers.

How Prices Are Determined

The supply of meat and the demand for it are two of the most important and interesting factors in our national life. They fluctuate and vary in abrupt fashion, and the ratio of one to the other continually changes. It is affected by this and by that, by the weather and by the prosperity —or adversity—of the country, and by many other factors.

It is interesting to consider exactly how the forces of supply and demand work to set the prices for meat. People are at a loss to understand why meat prices vary so frequently. They wonder, for example, why a cut of meat bringing a certain price on one day should sell for several cents more or less per pound a few days later.

The reason is simple: There has been a change in the ratio of demand and supply. Perhaps farmers sent more hogs to market than they did a week before; this increased the supply of meat, say of pork chops, but demand remained the same. With more pork chops to sell than there was a demand for, prices naturally moved downward. Lower prices, of course, usually move goods, and meat is a perishable product that must be sold promptly. On the other hand, it may be that there was no increase in the actual supply of pork chops. For no explainable reason, hundreds of thousands of housewives may have decided to serve ham or pot roast or lamb stew instead of pork chops, and, as a result, the consuming demand for pork chops may have declined.

Price factors also work the other way. When demand increases while supply remains the same, prices move upward. It happens as often one way as the other.

Price "ups and downs" occur in the livestock market as well as in the retail store. When large supplies of animals arrive, the tendency is for prices to decline, unless demand for meat suddenly expands. Meat, except that part of it that is cured—such as hams and bacon—must be marketed promptly; it cannot be held for a shortage to develop or a period of increased demand to come about. It must be marketed promptly, and when supplies are larger than the demand, the price naturally declines.

In the same way, the old, old economic law works upward from meat to livestock. When the demand for meat is brisk and the supply relatively short, livestock is in greater demand and prices naturally move upward. And here, as in the case of meat, the price factor works both ways. Over a long period, the "ups" are just as frequent as the "downs," and the range is just as varied.

There naturally is a substantial difference between the price which the farmer receives for his livestock and the price the consumer pays for such cuts as steaks, chops, and roasts in the retail meat shop he patronizes.

The thing chiefly responsible for this price difference is the fact that the animal is not all meat In general, only about 50 to 55 per cent of the live weight of cattle, 45 to 50 per cent of sheep, and 70 to 75 per cent of hogs is meat. Moreover, a meat animal is made up of different parts, which, to the retailer, become a variety of cuts. When one of these cuts is produced, all of the others are too. No farmer has been able to develop a steer that is all steak or a pig that is all pork chops, hams, and bacon. Notwithstanding this fact, many consumers appear to know only a few cuts and use them to the neglect of many other parts from which appetizing and nourishing meat dishes may easily be prepared.

Financing: Capital and Profits

From a financial standpoint, the meat-packing industry is characterized by large volume, rapid turnover, narrow margins, and moderate returns on investment.

In value of output, the industry is one of the largest, with aggregate annual sales in excess of $3,000,000,000 and a total capital investment of perhaps $715,000,000. This tremendous business has been conducted on margins of profit that, in recent years, have averaged under 1 cent on each dollar of sales. Even with the very rapid turnover obtained in the industry, the return on owners' investment in recent years has averaged less than 6 per cent annually.

The rapid turnover is due, in part, to the perishable nature of meat and some by-products; in part, to the prevailing practice of buying and selling largely for cash. The principal expenditures of packing companies are for livestock, all of which are paid for on the day purchased. Terms to customers rarely exceed 7 days on meats and other principal packing-house products, although slightly longer terms are sometimes extended on by-products and related items. Sales from one packing company to another are normally settled on the sight-draft basis.

In spite of the fact that a great many meats and meat products are sold within a few days after the purchase of the livestock from which they are produced, merchandise inventories frequently represent the largest class of assets owned by packing companies. Total current assets—including inventories, accounts receivable, and cash—will normally make up from 50 to 60 per cent of the total assets of a meat-packing company; whereas an average for all industries will probably be nearer 35 per cent, and some—like timber and mining companies—usually have not more than 20 per cent of their property in the form of current assets. As a result of this distribution of assets, the financing of packing companies tends to be more generally in the form of long-term funded debt than is the case with many industries.

One other factor influencing the financial policy of meat-packing companies is the seasonal accumulation of meat, which takes place during the winter months, when receipts of livestock are heavy. Total stocks of products stored by the industry are usually from 40 to 100 per cent greater on the first of May than on the first of November. This accumulation

of products requires substantial short-term financing by the packing companies. Borrowings are liquidated from the proceeds of sales as the stocks are worked down during the summer months.

The Importance of Meat as a Food

The best diet for the average person to consume is a well-mixed diet composed of a variety of foods. Such a diet should include green leafy vegetables, fruits, milk and other dairy products, and an abundance of high-quality animal proteins, such as meat supplies.

Proteins are the essential building materials of the body, indispensable to proper growth, repair, and good health. Meat supplies proteins of high quality and ready digestibility.

Meat is also an important source of fat, a great energy-producing food. Lean meats, since they are nutritious but furnish only modest amounts of calories, are recognized as especially important in the nonfattening diet. The fatter meats, however, are very rich in calories. Meats such as bacon and salt pork are among the richest of all foods in energy content.

Meat is a good or excellent source of iron and phosphorus, and supplies in good quantity most of the other minerals needed by the body. It is low in calcium, however, and one should use milk, vegetables, and other lime-rich foods to supply this need. Most of the vitamins also are found in meat, some in modest amounts only, but others, such as riboflavin (Vitamin G) and the pellagra-preventing vitamin, and, in the case of lean pork, thiamin (Vitamin B_1), are supplied abundantly. Parts of the animal such as the liver, kidneys, heart, tongue, thymus, and pancreas are excellent sources of both protein and minerals and, in addition, are rich in many vitamins.

The muscles of the meat animal that are exercised the most are generally not so tender as the less-used muscles. Cuts from these muscles, however, have an unusually fine flavor, and they have the added attraction of being relatively low in price. When properly cooked, they provide tasty, economical, and nutritious food.

Meat may be eaten in widely varying abundance, according to individual needs and tastes. Usually, it forms the basis of the diet, both from the planner's and the diner's standpoint, and successively higher income groups increase the quantity of meat in their rations as fast as they are financially able to do so. Some of the healthiest people on earth are the Eskimos and other groups which, for centuries, have lived on an almost exclusive meat ration.

Legislation Affecting the Meat-Packing Industry

The meat packer, since he stands midway between the producers of livestock and the consumers of meat, naturally has been a target for criticism from one group or the other whenever meat prices have been unusually high or livestock prices unusually low.

One reason for the criticism lies in the complexity of the industry itself

and the obvious difficulty of making clear to the consumer, on the one hand, why steak sells for 40 or 50 cents a pound when cattle sell for 10, and to the producer, on the other, why, when steak sells for 50 cents a pound, the packer cannot pay an equal amount for livestock.

The answer, of course, is that only about half the steer is meat and not all that half is steak (only a small percentage is, as a matter of fact) and that not even all steak sells for anything like 50 cents a pound Moreover, some of the much more abundant cuts may bring only a little above cost or, in some cases, even less than cost.

Through the development of by-products, the meat packer, from time to time, is actually able to pay the producer more for his cattle than their meat is to bring. The profits of packers, although seemingly large in total volume, are usually very small as compared with their sales volume (often the largest of any manufacturing industry's in the United States), or with the investment required, or with the profits of most manufacturing industries.

As early as 1889, following a period of low prices of livestock, a United States Senate committee investigated the meat-packing industry, without result, for evidence of combination for the purpose of lowering the price of cattle.

In 1912, several meat packers were tried on a criminal charge of restraining trade but, after a jury trial, were declared not guilty.

Following another agitation by livestock producers, the Federal Trade Commission investigated the larger packers in 1917 and 1918 and issued a denunciatory report. The packing industry, as well as impartial observers, believed that the Trade Commission had made an unfair and biased investigation. Inspection of data collected by the Federal Trade Commission by special attorneys employed by the Attorney-General and a grand-jury investigation failed to provide grounds for an indictment. Nevertheless, considerable public sentiment had been aroused by the publicity given the report of the Federal Trade Commission. To allay this feeling, the five larger packers agreed to what is known as the "Consent Decree," whereby they were to divest themselves of food lines other than meats and meat, dairy, and poultry products. The decree specifically said that the packers were not adjudicated guilty of unlawful acts and that the Consent Decree did not constitute an admission of guilt.

Following the report of the Federal Trade Commission, many bills were introduced into Congress to restrict the packing industry. The Packers and Stockyards Act was passed in August, 1921. It does not contain some of the radical features that were included in earlier bills but it gives the Secretary of Agriculture rather wide powers of regulation. Many have believed that the establishment of Government supervision of the packing industry is fraught with grave dangers. Whether or not it harms the industry depends upon how the law is administered. So far, it has been administered in an impartial and constructive way, but one dislikes to contemplate what might happen if, during future

political changes, the administration of the law should fall into the hands of prejudiced and unscientific men.

The American Meat Institute

The American Meat Institute, whose headquarters are in Chicago, is the trade, research, and educational association of the American meat-packing industry. The Institute conducts scientific and practical research, collects and distributes statistics of the meat and livestock industries, develops and issues publications and news announcements in behalf of its industry, conducts advertising campaigns, counsels its members as to product standards, operating or accounting procedures, and waste elimination, and offers employee training courses. Research of various kinds is carried on both in the laboratories of the Institute and, in some cases, in the laboratories of colleges and other scientific institutions, with funds supplied by the Institute. In furtherance of the industry's educational program, an Institute of Meat Packing has been established at the University of Chicago, conducted jointly by the University and the American Meat Institute. Educational and research activities are carried on also by the larger companies in the industry. The American meat-packing industry is eager to keep improving its operations and its service to producer and consumer.

4

The Fishing Industry

Early History of the Fishing Industry

Fishing possesses an ancestry perhaps as ancient as man himself. The earliest fisherman undoubtedly secured his prey by means of his bare hands. This method, we may surmise, was first exercised on fish left stranded in shallow pools by receding tides, or on fish spawning in shallow waters near shores. Shellfish—such as oysters, clams, and mussels—could be gathered on the shores between high and low water without the aid of any instrument.

The spear probably was the original instrument fashioned by man to secure fish lying in pools too deep for hand fishing, and then later for fish in open waters. The occasional loss of a speared fish perhaps suggested spurs or barbs, and a development of the spear harpoon with side barbs.

Fishing with a line of some sort was devised doubtless by a meditative Magdalenian observing how dropped morsels were seized by fish in a pool, the depth or environment of which made hand or spear fishing impossible. A thorn or a similar object serving as a hook attached to the line probably solved the problem of reaching and landing the fish.

The sequential development of fishing suggests the net as the last implement invented by primitive man for the catching of fish. Primitive nets were probably made by plaiting twigs or small branches of trees, tough grasses, the silk of cocoons, and many other materials.

The early Greeks and Romans fished with spears, hooks and lines, rods, and nets. Fishing, down to Roman times, continued to be more of a distinct trade than was the pursuit of animals and birds. The net, a quicker and surer implement, was principally used by the trade fishermen. Egyptians used all four methods of fishing in the Nile by 2000 B.C., while in China the earliest mention of fishing occurs 1122 B.C. In Assyria the hook and line and the net are the methods of fishing recorded Hand lines and nets were employed in Israel, where fishing was a principal means of procuring food. Every known method of fishing has been employed in China for thousands of years. In no other country except Japan is so much food derived from the water.

Early method of preservation. Preserving fish by means of salt was

Grand Bank of Newfoundland, Green, St. Pierre, Banquereau, Misaine, Canso, Sable Island, Sambro, Roseway, La Have, Brown's, Seal Island, and Georges.

All along the continental shelf within the 100-fathom curve are numerous rocky ledges, sand and mud patches, which are favorite fishing grounds for various species of bottom-feeding or demersal fishes. Between Cape Cod and Cape Hatteras there are no important offshore banks beyond the 100-fathom curve. There are, however, several extensive seasonal fisheries between the Gulf Stream and the coast, including the tile fishery, which is conducted along the edge of the Gulf Stream from about 80 miles off the coast of New Jersey southward to Maryland Off the Virginia Capes, an extensive winter fishery has been conducted for the past several years by vessels hailing from more northerly ports, principally Gloucester, Boston, and New York. During the winter months this fishery furnishes sea bass, porgies (scup), fluke, and several other varieties which, prior to the establishment of this fishery, were available only during the summer months—and then only from the inshore fisheries from Cape Charles to Cape Cod.

The fisheries of the South Atlantic and Gulf differ as greatly from those of the North Atlantic as the agricultural products of the northern regions differ from the products of the South. The Gulf Stream, flowing through the Straits of Florida, follows the general contour of the coast until it reaches Cape Hatteras, where the waters of the Arctic Current, flowing in an opposite direction, are interposed between it and the coast. From this point and northeastward the Arctic Current forms a cold wall of water covering the continental shelf upon which are the fishing grounds of the North Atlantic. South of Cape Hatteras, the influence of the Gulf Stream extends practically to the shore line, and it is in this warmer water that lie the fishing grounds of the South Atlantic.

North Carolina occupies a unique position regarding the coastal fisheries, as its most easterly point, Cape Hatteras, is the southern limit for several species of fish common in the more northerly waters; these are the cod, tautog, porgy, and mackerel. It is also the northern limit for many species characteristic of the waters of Florida and the West Indies North Carolina has the most remarkable coastal section of any state bordering the Atlantic seaboard. The peculiar character of this region has a great influence on the variety and abundance of fish life and has favored the development of most extensive fisheries. The outer shore, in the northern and central portions of the state, is simply a bar of sand separating the waters of the ocean from those of an enormous inland-sound system. The sounds communicate with the ocean either directly through narrow inlets or through other sounds. Many receive the drainage of important streams. The sounds in geographic order are: Currituck, Albemarle, Roanoke, Croatan, Pamlico, Core, Bogue, Stump, Topsail, Middle, Masonboro, and Myrtle, and they constitute a series such as exist in no other state. This area, besides containing valuable species of fish and shellfish, is exceedingly important as a spawning

ground and nursery for shad, alewives, striped bass, and other migratory fishes.

Off the shores of South Carolina and Georgia, at a distance of 10 to 20 miles, in from 10 to 18 fathoms of water, there is an irregular coral bank broken up into patches, several miles in extent, extending along the entire coast. The abundance of food on the banks, together with the shelter afforded by the corals, make them the favorite feeding grounds of immense schools of fish, chief of which is the blackfish, in consequence of which the grounds are known as "Blackfish Banks."

Along the shores and in the rivers and lagoons southward to Key West, vast quantities of fish, shellfish, turtles, terrapin, and shrimp are taken and shipped to markets throughout the country.

The fishing grounds along the shores of the Gulf states are quite extensive, and while they furnish many highly esteemed varieties of food fishes—including the sheepshead, pompano, several varieties of snappers, and groupers—the fisheries of this region are not especially important when compared with those of the other geographical divisions of the coastal states.

Off the coast of Alaska and extending all along the Aleutian Islands are extensive banks on which halibut are taken. Cod, sablefish, and herring are also important fisheries of the North Pacific. The salmon, which is the most valuable of the Pacific Coast fisheries, are taken principally in traps, pound nets, and gill nets in the rivers and inland waters of Alaska and southward to Central California. The tuna fishery, conducted off the coast from Central California south into Mexican waters, is second in importance only to that of the salmon; it also ranks among the most important of the fisheries of the world. American fishermen produce annually more than 20 per cent of the world's catch of these fish.

Shad and striped bass, transplanted from the Atlantic to California waters many years ago, now populate practically all coastal waters from the Sacramento River in California to Puget Sound; they support extensive fisheries throughout that entire region.

The vessel fisheries. The vessels engaged in offshore bank fishing are of three general types: the two-masted schooner, equipped with an auxiliary gas or oil engine; the dragger, or small trawler, equipped with a Diesel engine; and the large steam, or Diesel trawler. Line fishing, either hand line or trawl line, is exclusively employed by the schooners. The draggers and larger trawlers use a conical-shaped bag net, which is dragged on the bottom behind the vessel. The schooners range in size from a few gross tons to 60 or 70 gross tons; the draggers, from 50 to 200 gross tons; and the trawlers, from 300 to 500 gross tons.

Vessels fishing in inshore waters are of several types, including the small motorboat, the sloop, the ketch, the schooner, and the dragger. These are also to be found all along the Atlantic, the Pacific, and the Gulf Coasts, modified only to meet peculiar conditions or the kind of fishing in which they are engaged

On the Great Lakes, a peculiar type of vessel is employed to transport

the fish taken in the offshore traps to the shore plants. These vessels are called "tugs" and are built somewhat like the ordinary harbor tugboat, except that the deck is housed in, permitting the sorting, preparing, and packing of fish for market while returning to land.

Menhaden vessels, considerably larger than the trawlers, are equipped principally with steam engines. Some of the newer vessels, however, are propelled by Diesel engines. The superstructure of these vessels is usually at the after part of the deck, leaving a large section of the forward deck free for receiving the fish as they are bailed from the seines.

Off the Pacific Coast states, factory ships are employed in the sardine and herring industries. Fleets of smaller vessels supply these factory ships or floating canneries with the raw material, which is packed in cans of various sizes. By-products manufactured from the residue and factory waste are oil, meal, and fertilizer.

Diesel engines are rapidly displacing other means of supplying motive power in practically all modern fishing vessels. Diesel-driven fishing vessels develop greater speed, require less bunker space for fuel, and, in general, are more economical to operate. The holds of the modern trawler are insulated and some are equipped with mechanical refrigerating facilities.

Vessels furnish a large part of the fish with which our markets are supplied. The vessels, except those of the offshore bank fishermen, fish along the shores within 100 miles of the coast. The mackerel fisheries of the Gulf of Maine are the most important in the world. In the vicinity of Cape Hatteras, these fish make their appearance early in April and are sought by a great fleet of vessels, the majority of which hail from the New England States. The vessels are, for the most part, the same that fish on the banks for cod, haddock, and halibut, after the mackerel season is ended.

Herring furnishes one of the most important fisheries of both the Eastern and Western coasts. It is a valuable species, from the young fish a few inches in length, which supplies the Eastern sardine-canning industry with its raw material, to the mature herring, vast quantities of which are used in the fresh, salt, and smoked fish trades. Considerable quantities of herring are used as bait by the line fishermen for the capture of cod, haddock, and other "ground," or demersal, fishes.

In addition to the species already mentioned, the flounder, bluefish, weakfish, scup or porgie, tilefish, sea bass, menhaden, and several others support important vessel fisheries, of which the most important from the standpoint of tonnage landed is that of the menhaden. This fish is of great commercial importance, although sparingly used as food by man. It is one of the most abundant of all ocean fishes, and its range extends along the entire Atlantic and Gulf Coasts. The products manufactured from this fish are oil, fertilizer, and fish meal.

Nets and Traps

Enclosures formed by fences of wooden stakes and intertwined with branches placed at advantageous places in stream, lake, or sea have long

been employed in the fisheries. The openings of such traps are so placed that the natural course of the fish leads into the trap, and once in, it is difficult for them to find the exit. There are many variations in the form and construction of traps used in American fisheries. The most primitive of these is the weir.

Weirs. Weirs of brush, "brush weirs," are extensively used in the sardine-herring fisheries of Maine. The main body of the weir is a large circular or heart-shaped enclosure formed by driving posts, and smaller stakes in between, into the bottom of a bay or river. These smaller posts are usually fastened together by stringers attached to the tops of the larger posts. Fine brush is then interwoven between the small posts completing the enclosure. Netting or webbing is sometimes used in place of branches.

Pound nets. The principle employed in the construction of pounds is similar throughout the entire length of the coast, but the types range from the small inshore, single-heart trap to the very large elaborate pounds, set in 10 to 15 fathoms of water. In its simplest form the pound net consists of three parts: first, the leader, extending from shore or shallow water into deeper water and deflecting the fish into the second part; second, the heart, a heart-shaped enclosure with its apex at the mouth of the trap and its sides extending shoreward and outward from the end of the leader, its ends curved in toward the leader as well as toward the mouth of the trap; and third, the "pot" or "crib," usually rectangular in shape, in which the fish are captured. The leader is formed by poles driven down into the bottom, connected with coarse-meshed webbing, extending from the bottom to or slightly above the surface of the water at high tide. The bottom of the pot is covered with netting, which can be raised when the trap is fished. The entire pound, including the leader, is supported by poles driven into the bottom, set at intervals to conform to the shape of the heart and pot, and in sufficient numbers to prevent the trap from being carried away by rough seas.

Fyke nets. The fyke net is a long bag distended by a series of hoops, with or without side wings, which serve to deflect the fish into the funnel mouth. The hoops vary in number from 2 to 15 and in diameter from 2 to 6 feet, the first hoop being generally larger than the others. This form of gear is largely used in fresh-water fisheries for such species as carp, buffalo fish, catfish, perch, and so forth.

Eel pots. Eel pots are in general use along the Atlantic Coast from New York to the Carolinas. They are made of splints, wire netting, barrel staves, laths, or rattan. The length of the pot ranges from 18 inches to 3 feet. The usual type of pot has a funnel at one end made of netting 8 to 15 inches in depth. The other end is filled in with a piece of netting which may be opened and closed by means of a purse string. The pots are baited and are usually set singly, but in some localities they are set in strings of from 10 to 60 and from 15 to 60 feet apart. Bait consists of crabs, shrimp, clams, menhaden, fish heads, and so forth.

Lobster pots. Lobsters are captured in traps called "pots." These vary in shape and dimension in many sections of the country but operate

on the same principle. In general, they consist of oblong lath boxes in which bait is placed. They have one or more funnel-shaped openings through which the lobsters pass in their search for food. They are usually about 4 feet in length, 2 feet in width, and 18 inches in height. The funnels are about 1 foot deep, and therefore extend about halfway to the center of the pot. The captured lobsters are removed through a door located at the top of the pot.

Seines. These nets are long and usually rectangular. The upper edge is provided with floats and the lower edge with sinkers, to keep the netting distended while the fish are encircled and drawn out on shore or on a landing platform. Seines may be generally divided into two classes: the hawl, drag, or beach seines and the purse seines. The former are employed in relatively shallow water along the shores of rivers and in bays, while the latter are generally used in the deeper waters of bays and the open sea in the capture of fish which school at or near the surface. When a school of fish is sighted, the seine is laid around it and the bottom pursed or shirred together by the purse line, to prevent the fish from settling and thus escaping. This type of gear is extensively used in the menhaden and mackerel fisheries.

Gill and trammel nets. As the name implies, fish are caught in gill nets by becoming entangled in the netting, the size of mesh being determined by the particular fishery in which the net is to be employed. The mesh permits the passage of the head of the fish, but not the body; thus the fish is "gilled" and cannot escape. To be effective, such nets must be obscure in the water and of sufficient strength to hold the struggling captive without tearing the net. For fishing, the nets are either anchored or staked, or are permitted to drift with the tide or current. They may be so hung as to fish at the surface, or at intermediate depths, or at the bottom. Trammel nets represent a modification of the gill net. Instead of a single netting, there are three parallel lines of webbing, the outside webs being coarse-meshed while the inside web is fine-meshed The fish swims into the outer web, hits the fine mesh, carrying it through one of the meshes of coarse webbing on the opposite side, thus forming a pocket from which it cannot readily escape. Trammel nets have an advantage over the regular gill nets in that the fish will remain alive for a much longer time.

Otter trawl. The trawl net is a large, flattened, conical bag, the mouth of which is held open by two boards (doors), one on each side, to which are attached towing warps by chain bridles. These are so adjusted that, as the trawl is towed along over the bottom, the resistance of the water causes the boards to pull away from each other, each board and attached warp operating on the same principle as a kite. The nets are about 150 feet long, the foot line about 140 feet, and the head line about 110 feet at the mouth. The head line holds the top of the mouth considerably in advance of the bottom when being towed.

Beam trawl. The same type of net is used for beam trawling as for otter trawling, but in this the bag is attached to a beam, with iron frames or runners as its ends. The runners serve to prevent the net from burying

in the mud and to aid in keeping the mouth of the bag distended. The beam trawl is not as extensively used in commercial fishing as formerly but is employed largely in scientific collecting.

Paranzella net. The paranzella has been in use on the Mediterranean for a long period of time and was introduced into the California fisheries about 1880. The net is heavy and strongly constructed and is used principally in the capture of soles and flounders. It is rectangular in cross section, with a door at the posterior end for removing the fish. The net is towed by vessels separated from each other by a distance of about 250 yards.

Fishing Industry of the United States

It is quite certain that the Newfoundland fisheries were known to Biscayans and Normans as early as the year 1504. Four years later Thomas Aubert sailed from Dieppe to Newfoundland to engage in codfishing, and before returning to France explored the St. Lawrence River. In 1517, 50 ships of different nations were fishing regularly on the Newfoundland Banks. During the following years the number of vessels fishing in these waters was greatly increased. Before the year 1600, there were 150 French, 100 Spanish, 50 Portuguese, and 200 English vessels engaged in this fishery. These fisheries were regarded as one of the greatest sources of wealth then known to the world. Colonies were established in connection with the enterprise, first in Newfoundland and then on the mainland.

There is little doubt that the Pilgrims were drawn from Holland to America as much because of the fisheries as for a haven of religious freedom. At that time the Dutch fisheries were at the highest point of prosperity, and all Europe was intent on planting fishing colonies at Newfoundland and on the shores of New England. From the moment that Cabot discovered our continent in 1497, it had been known to the people of Europe that our waters teemed with fish. When the Pilgrims sailed from Holland in 1620, they were as well informed as others, and it is evident that the influence of the fisheries was a deciding factor in the selection of America as their final objective.

These colonists brought with them the arts of sousing and pickling fish, and the descendants of the Pilgrims are still pickling fish around Cape Cod, particularly in Gloucester. The city of Gloucester was founded in 1623, mainly for the purpose of conducting fishing operations, and at no time has this been secondary to any other enterprise. The cod is preeminently the fish sought, and as it brought succor to the colony in early times, it was designated as the "Sacred Cod."

Influence of fisheries. The interval between the discovery and settlement of North America is often regarded as a mere blank, and the opinion is prevalent that our fisheries have no history, except such as relates to the quantity and quality of food which they annually produce. But fishermen were the pioneers of British and French civilization in America. The intercourse they maintained between the two continents

kept alive desires which otherwise might have become extinct. The arrival upon our coasts of hundreds of fishing vessels within a century of its discovery gave rise to events that determined the economic and political history of the country.

During the four years after the landing of the Pilgrims, these colonists suffered severe hardships and starvation, and many died. The survivors subsisted principally on various kinds of shellfish that could be easily procured. In 1623 they were reduced to a single fishing boat, which although not seaworthy, helped in securing the fish on which they subsisted all that year.

The beginning of the fish industries in the colonies. In 1624, however, conditions had so far improved that the colonists sent a ship to England laden with fish, cured with salt of their own manufacture; and the following year they dispatched two others with fish and furs. In 1626 they opened a trade with the deep-sea fishermen of Monhegan and commenced voyages to different parts of Maine to procure fish and furs. Two years later we find them selling the products of the sea, as well as corn, to the Dutch on "Hudson's" River.

These trading operations of the Pilgrims may be considered to be the beginning of the fishing industry in the colonies. While fishing had been carried on by European vessels on the banks, and colonists engaged in fishing to supply their own needs, the Pilgrims were the first to export fish to Europe and to trade in fish with the other colonies.

New England fisheries in 1850. With the growth of the colonies and the establishment of new ones, there was a corresponding development of the fishing industry. There are no reliable statistics available prior to the year 1850, and so for that year only the codfish and mackerel as cured and packed are considered. Table I, covering the New England fisheries for the year ended June 1, 1850, was compiled by the United States Census Office:

TABLE I

STATISTICS FOR NEW ENGLAND FISHERIES
FOR YEAR ENDED JUNE 1, 1850

State	*Capital Invested in Dollars*	*Men Employed*	*Quintals Codfish*	*Barrels Mackerel*	*Value of Products in Dollars*
Maine..........	$491,430	2,732	173,094	15,241	$558,250
New Hampshire...	42,700	300	19,550	1,060	59,281
Massachusetts...	2,127,885	7,917	215,170	236,468	2,188,441
Connecticut......	279,300	911	—	—	261,683
	$2,941,315	11,860	407,814	252,769	$3,067,655

On the basis of quintals at 112 pounds and barrels at 150 pounds, the total quantity of cod and mackerel packed would be 83,591,000 pounds for the first three states named; based on the average value in these states.

the quantity packed in Connecticut would be 7,811,000, or a grand total for the New England states of 91,402,000 pounds.

Growth of the New England fisheries. According to a statistical report of the United States Fish and Wildlife Service covering these same New England fisheries 90 years later, there were produced 158,000,000 pounds of cod and mackerel, having a value of $4,000,000. During the past several years the average annual production of all the New England fisheries exceeds 700,000,000 pounds, valued at approximately $25,000,000. The haddock has become one of the most important of the New England fisheries. Recent improvements in manufacturing this fish into fillets has developed a market demanding vast quantities, which are distributed throughout the entire United States.

The growth of the industry in the United States has been remarkable. Large quantities of sea, river, and lake fish are shipped fresh to all parts of the country. An enormous quantity is used for canning, curing, and salting. In addition, shellfish—including oysters, clams, lobsters, and shrimps—supply the raw material for a great number of canneries as well as the demands of the market for fresh products.

The great fishing centers. The principal fishing ports of the United States in geographical order are: Portland, Maine; Gloucester, Mass.; Boston, Mass.; New York, N. Y.; Philadelphia, Pa.; Baltimore, Md.; Savannah, Ga.; Jacksonville, Fla.; Mobile, Ala.; New Orleans, La.; Galveston, Texas; San Diego, Cal.; San Francisco, Cal.; Portland, Ore.; Seattle, Wash ; Ketchikan, Alaska; Bay City, Mich.; Chicago, Ill.; Sandusky, Ohio; Cleveland, Ohio; Erie, Pa.; and Buffalo, N. Y. Scattered all along the Atlantic, Gulf, and Pacific Coasts, as well as along the shores of the Great Lakes and many of the inland rivers, are villages and towns whose principal industry is fishing. Many of these villages were originally small groups of huts used by fishermen on the shores in close proximity to fishing grounds. A considerable number of these villages have grown into towns and cities and are now popular as summer resorts. The larger cities, such as New York, Boston, and San Francisco, are distributing centers as well as landing ports. Fishery products are shipped to these centers from all parts of the United States and Canada, and large quantities are reshipped throughout the nonproducing areas.

Modern Methods of Commercial Fishing

The schooner. The greater part of the catch of fish in the United States is taken by vessels. These range from the small motorboat to the modern trawler. The schooner, which originated in Gloucester in 1713 and which is the only type of sailing vessel that is purely American in character, has been used in the fisheries continuously since that time. These vessels were formerly equipped with two masts, topsails, and a main sail of great size, a foresail, and a jib. They are now built without topmast and topsails, and are equipped with auxiliary gas or oil engines.

Schooners employ different types of gear according to the fishery in

which they are engaged. In the mackerel, herring, and menhaden fisheries, purse seines are used; in the blue fishery, hand lines are the principal gear; while in the weakfish and shad fisheries, and also in the capture of whitefish, the gill net is extensively used. The Spanish and king mackerel, the red snapper, and many of the Southern varieties are taken on hand lines. The salmon of the Pacific Coast are taken in traps, although a few are taken on trawl lines.

There are a great many small vessels engaged in local fishery operations. These boats are equipped with either crude oil or gasoline engines and are used principally in the flounder and scallop fisheries.

The sloop, a vessel with a single mast, is being rapidly displaced by the powered schooner and the motor trawler.

Line fishing. On the banks, line fishing is still an important method of taking cod, haddock, and halibut. This method is employed mainly by schooners in the salt-fish trade. Fishing is done from dories, and either hand lines or trawl lines are used. Hand lines are made principally of cotton and are of sufficient length to reach bottom; they are equipped with a sinker and hook, which is baited with herring, squid, or "pogy" (menhaden). Trawl lines are made of the same material as hand lines but are usually of heavier weight. These lines range in length from 1,000 to 5,000 feet and are equipped with "gangings" (lines about 3 feet long) at intervals of 6 feet, to which baited hooks are attached. At each end of the trawl an anchor and a buoy are employed to sink the line and to mark its location. The trawls are set in a suitable place and raised twice daily to remove the fish. A schooner may operate from 10 to 100 of these trawls, depending on weather and fishing conditions.

The otter trawler. The otter trawler is the most recent development in fishing vessels and is most effective in the capture of haddock, cod, flounders, and other bottom-feeding fishes. These vessels are exclusively employed in the fresh-fish trade. Enormous quantities of fish are taken and rushed to the markets of Boston, Gloucester, Portland, and New York. The larger trawlers fishing the banks are usually operated on a schedule. They leave port at a certain time, a prescribed time is set for fishing, and the return to port is determined to keep the markets constantly supplied with fresh material. These trawlers are equipped with radio apparatus and are in constant touch with their owners and other vessels in the fleet.

Preparation for Shipment

Fish that are landed fresh at points remote from distributing markets are packed in barrels or boxes for shipment. Uniform packages are generally used, boxes containing 50 pounds, 100 pounds, and 150 pounds of fish. Halibut and codfish are usually packed in 100-, 200-, and 500-pound boxes. Mackerel are packed in barrels containing 150 pounds. When barrels are used for other varieties, 200 pounds is the quantity packed.

The method of packing is as follows: A layer of cracked ice is put on

the bottom of the container; a layer of fish is then placed on this bed of ice, another layer of ice is spread over the fish, and on this is placed another layer of fish. The process is repeated until the package is filled. Invariably the top layer is of ice. The cover of the package is then fastened on, the package is tagged, and delivery is made to the transportation company.

Vessels and boats landing their fares directly at the wharves of a canning or manufacturing plant have the fish removed by means of conveyor systems or baskets. The fish are received at the plant in a huge hopper, from which they are automatically conveyed to the washing and cutting sections.

Packaged fish. Fresh fish in packages for retail distribution constitutes the most important development within the past decade. Large fish, such as halibut and cod, are cut into steaks; haddock and hake, flounder or sole, and other fish of medium size are filleted; smaller fish, such as butterfish, sea bass, porgies (scup), and whiting, are dressed ready for cooking.

Consumer demand for prepared fish has encouraged the development of fisheries for several species hitherto unknown in our markets, except in areas local to such fisheries. Among the species prepared in filleted form that have gained in popularity and in consequence have become important products are the rosefish (*perca marina*) marketed under the name of "sea perch" or "red perch," groupers, red snappers, and a few varieties of fresh-water fish. The fish are prepared in large plants near points of production Much of the work of cleaning, wrapping, and packaging is done by machinery.

The advantages of packaged fish are numerous. The entire piece purchased by the consumer is edible; the price charged for it is fully competitive without any allowance for waste; there is no cleaning to be done by the purchaser, and the fish is ready to be broiled, fried, or otherwise cooked without further preparation; the shipping weight of the fish is reduced; the waste, which is usually about 50 per cent of the round fish, remains in the hands of the producer; packaged fish receive a more careful and cleanly handling all along the line from producer to consumer, for the reason that they are wrapped, are more delicate, and will not endure the rough handling that round fish are subjected to.

Freezing for preservation. Refrigeration is the only method of preserving that keeps fish in essentially their original condition over long periods and during transportation over long distances. Fish are highly perishable and the supply is highly irregular. Nearly all fish are migratory, and they have their seasons of abundance and scarcity. Weather influences the capture, and chance plays an important part in locating schools of fish. The causes that influence fluctuations in demand bear no relation whatever to the causes that control the supply. Under such circumstances refrigeration is absolutely necessary in order that the industry may meet the demand with the available supply without ruinous waste.

Fish entering a plant to be frozen are first washed and then placed in

large pans, in which they are conveyed to a sharp freezing room, where a temperature of about 15 degrees below zero F. is maintained. When the fish are solidly frozen, they are packed in boxes and placed in storage rooms where the temperature is held at from 0 to 5 degrees above zero F.

Brine freezing, popularly known as "quick freezing," is used principally in connection with fillets and other packaged fish. The fish are either immersed in the brine or are spread on metal plates that float on the brine in a shallow insulated tank or trough. Temperatures of the

Courtesy Atlantic Coast Fisheries Co.

Fig. 2 Fillets being frozen on metal plates floating on a brine trough. The plates are carried along by means of an endless chain belt and a circuit of the trough is made in about 30 minutes. Temperature of this brine ranges from 15° to 50° below zero.

brine range from 15 degrees to 50 degrees below zero F., and the time consumed in freezing fillets and other small fishes is from 30 to 60 minutes. There are several methods of quick freezing in general use throughout the industry. Those invented by Birdseye, Kolbe, Ottesen, Petersen, Taylor, and Cooke are the principal ones employed.

Canning

Canning of fishery products has become an important industry that provides the consumer with a wide range of sea food in a convenient and popular form. Canning of fish in the United States dates from about

1820, when Thomas Kensett and Ezra Daggett started the canning of lobsters and other sea food in New York City. Canning preserves to a large extent the natural flavor of the original food, and at the same time it can readily be transported and kept in any climate without appreciable deterioration. In fact, canned foods have all the advantages of fresh foods, prepared and cooked in the home.

The canning of salmon, sardines, shad, tuna, herring, mackerel, cod, haddock, and roe has reached commercial importance in this country. The salmon-canning industry is the most important fishery industry in America. It is located on the Pacific Coast from Monterey Bay in California to the Yukon River in Alaska. Sardines are canned along the entire coast of Maine and in California from Monterey to San Diego. The American tuna industry is situated in southern California. Sardines, mackerel, herring, anchovies, roe, and tuna are canned in various ways in several European countries, while salmon, swordfish, and crabmeat are canned in Japan and along the coast of Asia. Canada contributes very largely to the production of canned salmon. The canning of lobster is confined almost exclusively to the Maritime Provinces of Canada and to Newfoundland.

Process of canning. The fish, after being cleaned and trimmed, are placed in a brine bath to draw the blood from the tissues and to give the flesh a proper degree of firmness and the desired salty flavor. Many varieties are subjected to some cooking or drying process before being packed into cans, salmon being the notable exception. In the case of sardines, one of two methods is usually followed: the fish are either steamed and dried before packing or they are dried first and then cooked by a frying process.

The nature of most fishery products makes it practically impossible to pack them mechanically, with the exception of salmon. Therefore nearly all fish products are packed by hand.

Preparation of containers. Cans in which the fish are packed are usually put through a sterilizing and vacuum process before sealing. The use of solder in sealing has been almost entirely displaced by the more modern method of rolled seams. The use of glass jars in canning certain varieties of fish is gaining favor, and these have displaced tin to some extent. The jars are sealed in a vacuum-exhaust sealing machine.

There is no Governmental inspection of fishery products entering the canning trade. There has been no need for this, as each cannery packs its products under a brand name and unhealthful or inferior products would react against the packer, either forcing him out of business or compelling him to improve his product In addition, Federal and state laws impose heavy penalties for the adulteration and misbranding of canned and packaged foodstuffs.

By-Products—Their Uses and Importance

The residue or waste in a fish cannery or manufacturing plant is utilized in the manufacture of meal, fertilizer, and oil. In a large plant

this waste material assumes important proportions, as it aggregates approximately 50 per cent of the raw material entering the plant.

Fish oils. Fish oils are obtained from all parts of the fish, whereas fish-liver oils are prepared from the livers only. The bodies of liver-oil-yielding fish, such as cod, are as a rule very lean and yield very little oil, whereas the livers of fatty fish usually contain little oil. Cod-liver oil is a product of the cod fisheries of both the Atlantic and Pacific Coasts, but its most important center is Gloucester, Massachusetts.

There are several methods of extracting the oil from the livers. Medicinal oil is prepared only from absolutely fresh livers, while the oil from stale livers is used in various trades. The vacuum boiler is the most recent method employed in rendering medicinal oil.

Within the past few years, the development of methods of refining and blending various fish oils is making possible the concentration of a wide range of vitamins and large numbers of vitamin units in small gelatin capsules or pearls. These capsules, containing various vitamin combinations, have in large measure displaced raw cod and other fish-liver oils and their emulsions in the treatment of disease.

Salmon, sardine, and tuna oil are produced from cannery waste. The oil is obtained by cooking the waste in a steam retort either with or without pressure. Some methods of cooking make unnecessary the process of pressing, the oil rising to the top of the mass is syphoned off.

When pressing is required, the hydraulic type of press is commonly used. The cooked fish is permitted to flow upon a receptacle arranged for it upon a truck. When the charge has been completed, the truck with its burden is wheeled into the press. The pressure is applied until the maximum power of the press has been reached or until no further amount of water and oil can be removed. Fish oil as a by-product of the canneries augments the supply obtained from the menhaden, whale, shark, and porpoise fisheries. Fish oils are used in the manufacture of soap, paints and varnish, linoleum, leather, waterproofing compositions, certain lard substitutes, and for many other purposes.

Fertilizers. Fish waste from manufacturing plants, canneries, and large markets forms the chief source of the raw material for the manufacture of fish fertilizer. The "cake" (scrap that has been through the press and the oil extracted) is either acidulated with sulphuric acid or dried with hot air or steam.

Fish scrap has met with great success as a fertilizer and now constitutes one of the important sources of organic nitrogen. Its use is familiar to all fertilizer dealers and to most farmers who used unmixed fertilizers. Large quantities are mixed with other fertilizer components by the manufacturers of the scrap to form the so-called "complete fertilizers" and are sold generally under brand names.

Fish meal. While the fish-meal industry is one of the novel industries of America, the feeding of fish and fish scrap to animals is by no means new. As early as 1833 cattle at Provincetown, Massachusetts, were fed upon fish; and in 1864 the feeding of pressed herring scrap was

recommended by Dana of Maine, and feeding trials with menhaden scrap were suggested.

In recent years the use of fish meal as a stock and poultry food has grown rapidly. The by-products factories of the Pacific Coast have been quicker to manufacture scrap especially for meal than those of the Atlantic Coast. Doubtless this may be accounted for in the difference in the size of the factories on the two coasts and the recent development of the industry in the West.

Fish meal must be carefully dried and ground into either granular form for chicken feed or into a fairly fine meal for other purposes.

Other by-products. Other by-products of the fisheries include caviar, prepared from the eggs or roe of the sturgeon, spoonbill, catfish, salmon, and fresh-water mullet; pearl essence, procured principally from the scales of herring and shad; pearl shell, procured from the fresh-water mussel and abalone fisheries; and glue and leather, procured from fish skins.

Modern Refrigeration in Transportation

In cool weather fresh and frozen fishery products may be transported in small lots in ordinary cars for short distances. The shipment of frozen fish in warm cars is not very satisfactory, however, if the fish are to be kept frozen after arrival at their destination. For the great bulk of both fresh and frozen fish shipped refrigerator cars are used. These are railway freight cars, fully insulated with felt and fitted with doors equipped with compression bolts for tight closure. In each end of the car is a space or "bunker" for ice, or for ice and salt. Each bunker is provided with a hatch at the top for charging with ice and with drain pipes with traps at the bottom for discharge of brine. To allow circulation of cold air, there is an aperture about 1 foot wide at the top and bottom of the partition between the bunker and the body of the car. A heavy wire screen prevents the ice from falling through these openings. Usually the cars are refrigerated by packing the ice chambers with cracked ice and salt, the capacity of the two bunkers being 12,000 to 15,000 pounds of ice. Salt is mixed with the ice in the proportion of 10 to 15 pounds of salt to 100 pounds of ice.

Refrigerator trucks. The refrigerator truck has made its appearance in automobile transportation. These truck bodies are equipped with a single bunker or tank at the top, with pipes running horizontally under the roof. An arrangement of valves causes the brine to circulate in the pipes when the truck is in motion and provides the necessary refrigeration.

Solid carbon dioxide. Dry ice, or carbon-dioxide ice, is used to some extent in fish transportation in refrigerator cars and trucks. Its present cost as well as its extremely low temperature (109 degrees below zero F.) make its general use prohibitive, although it has possibilities as a refrigerant for individual packages of fresh and frozen fish.

Silica gel. The latest development in refrigerator cars is that manu-

factured by Safety Refrigerating, Inc., and operates mechanically. Silica gel is the refrigerant employed. An advantage of this type of transportation is that uniform temperatures may be maintained throughout a trip. Thermostats control the absorption and discharge of heat by the refrigerant and insure a shipment's arriving at its destination in perfect condition, regardless of the distance or time in transit.

Methods of Marketing Fish Products

Fresh fish are either landed directly at or shipped to wholesale distributing markets. These markets are located in the principal cities, not only on the seaboards but also in the interior of the country. A description of the methods in Fulton Fish Market, New York City, which is the largest wholesale market in the United States, will serve as an example of wholesale distribution.

About 500,000,000 pounds of fishery products are handled in Fulton Market annually. Of this amount upwards of 50,000,000 pounds are landed directly at the market wharves by fishing vessels, and the balance arrives by railroad, steamer, and motor truck. Products from every section of the United States and Canada, as well as from Europe, Asia, and Africa, are received regularly. Approximately 80 per cent of the total receipts of fish is distributed within the metropolitan area; the other 20 per cent is reshipped to points mostly within 200 miles of the city. More than 100 varieties of fish and sea food are handled during a year; haddock, cod, tile, flounders, and mackerel constitute the greatest volume.

Receiving consignments. When a shipment is received, whether a shipload, a carload, or an individual package, the consignment is given a mark or number for identifying purposes. A record is made in a receiving book showing the name of the shipper, the number of packages, kind of fish, how transported, and other pertinent data. The consignment is then delivered to the section or department in which the particular variety is handled.

Shipping wholesaler. As the fish are sold, the salesman calls to a salesclerk in the office the mark, weight, and kind of fish, and the purchaser's name. A porter gets a sales slip from the office, which he delivers with the fish to the customer's truck. When goods are to be shipped, the same procedure is followed except that the fish is delivered to the shipping department, where it is checked against the sales slip, packed, tagged, and delivered to the transportation company.

When a consignment is completely sold, the record is sent to the bookkeeping department. There an account sales is made showing the total sales, the amount of commission and transportation charges, and the net amount due the shipper. A check covering the amount is drawn and mailed, completing the transaction. When a wholesale dealer purchases goods from the shipper, the account is handled like any other merchandising transaction.

Packaged fish. Packaged fish is merchandised through markets, chain stores, and department stores. These fish, in either fresh or frozen state,

are as desirable to handle as any packaged food. The packages are dry and odorless and may be kept in a refrigerator with other products, such as butter, without fear of damaging such products.

The market for fresh fishery products has been greatly broadened since the advent of modern refrigerator railway cars and motor trucks. There is scarcely a part of the United States where fresh fish is not available. Frozen fish, especially sea products, are marketed throughout the Central and Midwestern states to a greater extent than on the coasts. Although freezing fish during producing seasons furnishes a supply of practically all varieties throughout the year, certain varieties such as cod, haddock, and Spanish and king mackerel—are produced at all seasons.

Competition in the Industry

While there is competition between wholesale fish dealers in supplying the retail trade, the real competition lies between the industry and other food industries. A consumer utilizes a certain amount of foodstuffs within a given period; when his demand is satisfied with meats and other agricultural products, the market for sea foods is seriously affected. Producers of patented breakfast foods, fruit growers, meat packers, and producers of other foodstuffs create competition through advertising and publicity. The fishing industry has not been able to advertise its products properly because of its widespread interests and the financial condition of the great majority of the producers. The larger companies packing fresh, frozen, and canned fish products under brand names do, however, advertise their products.

Financing

The greater part of the annual supply is produced by the small fisherman, whose investment in gear and equipment does not exceed a few hundred dollars. Some vessels are owned by individuals and others by two or more fishermen. The large trawlers are owned principally by fishing companies who operate manufacturing plants or wholesale distributing markets. The investment in individual vessels ranges from a few hundred dollars to $400,000.

Most of the larger companies are incorporated and are capitalized through the sale of stock. A few have issued bonds, secured by equipment or other property. Many of the packers and larger dealers who carry large inventories negotiate bank loans against warehouse receipts or company notes. These liabilities are usually liquidated as inventories are reduced.

Capital Involved in the Industry

There are no available figures covering the amount of capital involved in the industry. A conservative estimate of the amount invested in property and equipment directly connected with production would be

about $100,000,000. The investment in canneries, manufacturing plants, and wholesale establishments would probably exceed another $100,000,000. Liquid working capital probably aggregates $50,000,000.

Catch and Value of Fishery Products

The average annual catch of fishery products in the United States and Alaska aggregates approximately 5,000,000,000 pounds. Of this quantity about 3,150,000,000 pounds are food fish and the remaining 1,850,000,000 pounds are nonfood fish. About 1,500,000,000 pounds are utilized in the canneries, 110,000,000 pounds are frozen, 250,000,000 pounds are cured, 540,000,000 pounds are manufactured into packaged products, and 750,000,000 pounds are marketed fresh. After manufacturing and processing, the net weight of all fishery food products reaching the consumer approximates 1,950,000,000 pounds. Cannery waste, manufactured into by-products, and shrinkage in weight in the processes of curing account for about 1,200,000,000 pounds.

The total value of all fishery products and by-products in the hands of the consumer, including the cost of producing raw material, manufacturing and processing costs, transportation, costs of distributing, and so forth, exceeds $1,250,000,000.

Persons Engaged in the Industry

More than 125,000 persons are engaged in commercial fishing and 4,000 in transporting fishery products. The canneries and other plants employ more than 200,000 persons. In the wholesale establishments approximately 100,000 men and women are employed. Considering all phases of the industry, it gives employment to more than 500,000 people.

Legislation

The Federal Government does not have jurisdiction over the fisheries except in Alaska. Each state exercises its sovereign right over the fisheries within its territory. The Federal Government, through the Fish and Wildlife Service of the Department of the Interior, coöperates with the various states in many ways. It conducts scientific inquiries and surveys, gathers statistics, operates fish-cultural stations and laboratories. National legislation that affects the industry to any extent is limited to transportation and interstate commerce.

In practically every fish-producing state, there is a fish commission charged with the enforcement of laws governing the fisheries. These laws cover seasons when certain varieties may be taken and sold, the size limits of certain species, sections where fishing may or may not be done, determining and collecting license fees, the size mesh of nets, the locating of pounds and other traps, and many other measures.

At nearly every session of a state legislature, bills intended to restrict commercial fishing in one way or another are introduced. Most of these

bills are proposed by selfish interests without regard for the loss of employment or capital that might be involved should they be enacted into law. In the states where the fishing industry is an important factor, few bills inimical to the industry become law. In these states there are, however, laws intended wisely to conserve and perpetuate the resources. Practically all the laws governing commercial fishing operations have been introduced or sponsored by the fisheries industry.

Important Companies

The Booth Fisheries Company, with headquarters in Chicago, is the largest concern in the industry. It is engaged in production, canning, salting and curing, freezing, and wholesale and retail distribution. Its plants and establishments are scattered throughout the country.

Next largest is the General Seafoods Company, a subsidiary of the General Foods Corporation, located in Boston, with producing plants in Gloucester and in various production areas. This company operates the Bluepoints Company, The Rhode Island Oyster Farms Company, the Connecticut Oyster Farms Company, and the Long Island Oyster Farms Company. It conducts the largest oyster business in America.

Chesebro, Robbins & Graham, Inc., Fulton Fish Market, New York City, conduct the largest individual wholesaling establishment in the United States.

The Andrew Radel Oyster Company, Lester & Toner, Inc., and J. & J. W. Elsworth Company are among the largest growers of cultivated oysters. Their business is very extensive, covering the entire country.

The New England Fish Company of Seattle, Washington, is a large producer of halibut and salmon. It operates canneries in Washington, British Columbia, and Alaska.

While there are many other concerns on both the Atlantic and Pacific Coasts, and on the Great Lakes, whose business is very extensive, they are not so well known outside the industry.

Possible Future Developments

During the past decade there have been greater developments in the industry than at any previous time. The modern trawler has made possible an adequate supply of raw material for increased demands of the fillet business. Packaged fish is rapidly gaining in popularity, and new varieties are constantly being added to the line.

Science has played an important part in recent developments in the industry, and there is every reason to believe that it will continue to develop new methods of packing, new products, more economical operations, and the means of wider and better distribution. In the field of production, engineering, biology, bacteriology, and other technological studies will be of the utmost importance in coördinating supply, manufacture, and distribution.

5

The Lumber Industry

History of Lumbering in the United States

Lumbering began in the United States immediately upon the arrival of the first settlers. The whole Atlantic Coast was a forest region, and the pioneers thus found at hand material especially adapted to their housing needs. Of the 2,000,000,000 acres of the United States, exclusive of Alaska and the island possessions, more than 800,000,000 were timbered. Wood is easily worked and infinitely adaptable to industrial uses, and on account of its insulating properties, peculiarly suited to house-building in severe climates. More than half the American people live in wooden houses. The wealth of variety in the American forests is unequaled; there are over 1,100 different tree forms, of which about 150 have commercial value, and 29 yield important quantities of lumber.

In the English-speaking settlements the manufacture of boards and other utilizable forms of wood was at first entirely a matter of hand labor with ax, saw, wedge, and sledge. Sawmills utilizing water and even wind power were developed on the continent of Europe as early, perhaps, as the middle of the fourteenth century, but the opposition of the wood-working guilds had prevented their introduction into England. Consequently, at first all lumber manufactured in the English settlements was hewn or hand-sawed. After the invention of a two-handed saw, pit-sawing was used; the log was either placed over a pit or on high wood horses and one sawyer stood on or above the log and the other underneath. It is said that in some remote rural regions of the United States the pit-sawing method is still occasionally used for the production of lumber for home use.

Early sawmills. The early settlers of Virginia imported a number of workers from the continent, and it is likely that mills utilizing some sort of power were in operation in the Old Dominion soon after its settlement in 1607. The Dutch also used power in sawing lumber in the early days of their Manhattan settlements. The favorite form of applied power was that of the water wheel, and the numerous creeks and rivers of New England, which run to the sea through great forests of white pine and other utilizable timber, supplied power at the source of the raw material.

The first commercial mills of any size, therefore, may probably be accredited to New Hampshire or Maine as early as 1630.

Development of machinery was very slow, and it was 75 or 100 years later before there were individual mills of a capacity of 4,000 or 5,000 feet of lumber a day. Water power developed on a small scale, and applied crudely, had limitations in addition to the fundamental one of being necessarily used, prior to the discovery of electricity, at the site where the power is developed. The discovery of the steam engine and its application to sawmilling were consequently a great boon to the lumber industry. The first steam sawmill in the United States, erected in New Orleans in 1811, was promptly destroyed by a mob of angry laborers who saw the end of their occupation in steam power applied to saws.

The great era begins. The introduction of steam power and the extension of sawmills, whether motivated by steam or water power, did not proceed rapidly until about 1840, when, it may be said, the development of the Middle West began on a great scale. Before that time the manufacture of lumber was largely a local industry, the product of which was consumed mostly in meeting the modest building requirements of communities near the mills; but from 1840 onward there was a tremendous expansion of the lumber industry in order to meet the housing and other shelter requirements, as well as the industrial demand of the greatest population movement in the history of the world. The prairie and plains states were without sufficient timber, if indeed they had any, to meet the requirements of their rapidly growing populations, and so there sprang up an organized industry and commerce in lumber. The lumber industry, which had developed to meet local and exp[illegible]uirements mainly in New England, saw its center of gravity move [illegible] westward to New York, which was at the head of the indu[illegible] in England[illegible]ies of the nineteenth century; to Pennsylvania, which led i[illegible]liza[illegible]d seventies; then to Michigan in the eighties; and to Wis[illegible], [illegible] Minnesota in the nineties. This westward trek of the lumb[illegible]we[illegible]wed the zone of the white pine forests.

White pine and Western settlement. White p[illegible]e wood and is easily worked. Its vast forests were on the n[illegible]d to the immediate east of the new developing region. Water tr[illegible]sport was available on the Great Lakes and the Mississippi and Ohio Rivers and their tributaries. Hundreds of thousands of men were employed in the forests, in the mills, and in transporting logs and lumber. The Mississippi River and its branches conveyed thousands of rafts and millions of feet of lumber and logs for hundreds and even thousands of miles from mill to consumer. As the railways came in, the sawmill and the settlements of the plains and prairies were connected by direct and fast transport. The forest states, which were not adapted for prompt agricultural use on account of their forest coverage, thus easily became industrial states and contributed powerfully to the development of the agricultural regions. It is probable that the settlement and general progress of the Great Plains states would have been set back at least a generation if it had not been possible for the treeless regions to draw freely on the vast

forests of the Great Lakes states. The forests were literally moved to the plains and converted into millions of structures. This epoch of the conquest of the West by the employment of the forests was perhaps the mightiest in the history of the Republic.

Ownership of timber. In the colonial days the forest lands were for the most part the property of the Crown, and the British Admiralty endeavored to reserve the best trees for masts and spars for the Royal Navy, such trees being blazed and marked with the symbolic broad arrow. The colonists resented the royal prerogative, and from the first there was wholesale poaching upon the forests. The resulting friction was one of the contributing causes of the popular dissatisfaction with British rule which led to the Revolutionary War. Lumber, masts, spars, and staves for rum and wine casks were among the chief exports of colonial New England, mainly to the West Indies and to England. In addition, the abundance of timber mothered a flourishing shipbuilding industry.

In getting out the lumber, the trees were usually felled in the winter and the logs were drawn by oxen to the banks of a creek or river; thence they were floated in the spring to the mill; and if it was not on deep water, the lumber was subsequently rafted to the nearest port. The Merrimac, the Penobscot, the Kennebec, the Connecticut, the Hudson, and the Susquehanna were famous highways of logs and lumber for more than a century.

Lumber turns southward. As the depletion of the virgin timber of the North, mostly pine in the early days, progressed, the industry turned its attention to the yellow pine forests of the South. These, as well as oak for shipbuilding and other woods for industrial and domestic purposes, had been utilized from the earliest days of Southern settlement, but it was not until the last decade of the nineteenth century that lumbering *became a large-scale industrial enterprise in the Southern states.* This development was largely due to the enterprise and capital of the Northern lumbermen looking for new fields to conquer.

Opening up the Pacific Coast. The discovery of gold in California in 1849 and the subsequent large influx of population marked the beginning of the lumber industry on the Pacific Coast. Its source of material at first was mainly the redwood forests of tree mammoths along the coast north of San Francisco, between the ocean and coast range of mountains, extending into Oregon. Almost simultaneously, the great Douglas fir forests of the coast of Washington and Oregon were opened up, partly to supply local requirements, but mainly for shipment to San Francisco for distribution in California. At the same time mining development tapped the pine forests of the Rocky and Sierra Mountains.

Expansion of the industry. It is probably true that up to 1840 there was almost as much timber standing in America as when the country was first settled. In the early days, when the industry was local and of small proportions, only the best trees were selected and there was ample opportunity for later cuttings of the trees that were left. It is doubtful whether the cut was much, if any, greater than the annual regrowth. As timber became scarcer, close cutting was introduced and natural regen-

eration set back. As people swarmed into the upper Mississippi Valley in the decade of 1840 to 1850, there sprang up a multitude of mills, mostly of small capacity, until there were as many as 45,000. The total production of lumber, which had been only 1,000,000,000 feet in 1840, increased rapidly and continuously during the next 65 years. The crest of production was reached in 1907, when the output was 46,000,000,000 board feet. Since then there has been a gradual although uneven decline, until the present normal production is around 35,000,000,000 feet a year. Various causes have contributed to the decline, but the chief one has been the increased cost to the consumer, owing to the long freight haul, as the mills have become farther and farther away from the great consuming centers. Whereas 50 years ago the average lumber haul (and a large part of that by water) was 200 or 300 miles, it is now 800 miles. Another cause is the increasing competition of other materials.

In later years the tendency has been, on the whole, for the small mills to yield to larger mills. There are still somewhere from 15,000 to 20,000 sawmills in the United States, but about 90 per cent of the lumber production is derived from 4,260 mills, and of these, the 750 mills cutting 10,000,000 feet or more annually produce 70 per cent. As compared with the mills of the seventeenth century with their petty capacity of a few hundred feet a day, mills of a capacity of 50,000 to 200,000 feet are now common, and there are some that can produce 1,000,000 feet a day. The latter figure may be visualized by stating that 1,000,000 feet of lumber are sufficient for the erection of about 70 6-room all-lumber dwellings.

Leaders in the lumber industry. In all the Northern and Eastern forest states, where lumber became a major industry, its pioneers were conspicuous among the commercial, social, and political leaders of the time. Lumber was virtually the first manufacturing industry in those regions and was the chief early mobilizer of capital and the main source of industrial payrolls and dividends. Great numbers of its proprietors became wealthy and supplied capital for the innumerable later industries that took the place of the sawmills as the latter migrated to the West and South.

As the center of the lumber industry moved westward, the great lumber towns of the past, such as Bangor, Albany, Williamsport (Pennsylvania), Bay City, Muskegon, Grand Rapids, Eau Claire, Wausau, and Minneapolis, and such lumber distributing cities as Buffalo, Detroit, Milwaukee, and St. Louis, became the homes of many men of wealth made from the forests. Their story was repeated in later decades on the Pacific Coast and in the South; in San Francisco, Portland, Spokane, Seattle, Tacoma, and in New Orleans, Memphis, Houston, Jacksonville, and other cities. Naturally dominant men in a dominant and highly masculine industry, they became leaders in political and social life, and founders of family dynasties that are still powerful.

Chief Lumber Species

While, roughly speaking, all of the United States east of the Mississippi River was covered with forests, which even extended beyond the Mis-

sissippi in the Far North and in the Southwest, a large part of the timberland, especially that in hardwoods, was early taken over by agriculture, so that lumbering was only an incident of land clearing, and vast areas were cleared entirely by the use of the ax and fire. Nevertheless, there were extensive lumbering operations throughout the hardwood belts of the Appalachian and Middle Western states, but today the two leading lumbering regions of the country are the Southern states and the Pacific Coast, especially Washington and Oregon with a third, although less important region, in the Rocky Mountain states. By far the largest item of lumber produced in the South is southern pine; Louisiana, Alabama, Mississippi, North Carolina, and Arkansas lead in the order named. Southern pine is today the chief product of American sawmills; the total production in 1939 was 7,691,604 feet. Next in group rank is Douglas fir, produced in 10 states to a total of 6,554,781 feet, but chiefly in Washington and Oregon. Washington is now the major lumber producing state, with a total of over 7,000,000,000 feet, and Oregon follows with slightly less than 5,000,000,000 feet. Oregon leads in standing timber. If the western pines output of the Rocky Mountain and Pacific Coast states, and also their hemlock, cedar, and spruce are taken into consideration, the Far West can be said to produce somewhat more than half the annual lumber output of the United States. In point of present production by species, after southern pine and Douglas fir come the western pines, oak, hemlock, gum, maple, spruce, cypress, and redwood. Hardwood lumber constitutes about 20 per cent of the whole output.

The principal source of hardwood lumber, which is derived from deciduous trees, is in the southern Appalachian region and in the lowlands of the lower Mississippi. Among the species produced in these districts are varieties of oak, gum, chestnut, tulip (yellow poplar). The northeastern and Great Lakes states continue to produce considerable quantities of such hardwoods as oak, maple, beech, elm, and birch. Cypress is an important factor in the lower Mississippi Valley and the Gulf states. Most of the softwood lumber still produced in New England or in the Northeastern or Great Lakes states is spruce or hemlock; there is also some white and Norway pine.

Timber Holdings

Private acquisition of timberlands. All the timberlands of America, like those of other countries, originally derive from public title. In colonial days timberland was obtained largely by land grants from the British proprietors, and in later days by purchase from the state governments in the original colonial regions; but in the Northwest Territory and in all the rest of what is now the United States, which come directly under the sovereign power of the Federal Government, lands were obtained in large tracts mainly by private acquisition of lands granted by Congress to encourage the building of highways and railroads, and schools and colleges. In smaller units these Federal lands passed into private ownership through the Homestead, Stone and Timber, Preëmption, and

other acts which gave title to settlers. Except for the large tracts which were purchased by lumber companies from state institutions and other public grantees, the holdings of these companies were built up by acquisition of small tracts from individuals who availed themselves of the various public land acts. Title to the land was usually acquired in such cases, but sometimes, particularly in the South, the stumpage rights—that is, the timber rights—were bought.

The public forests. The public land policy of the United States originally contemplated the complete alienation of the public domain, since it was believed that the private ownership of land and all that belonged to it was the way to build up a prosperous nation. However, in the last quarter of the nineteenth century, the feeling became rather general that the Federal Government and the states ought to take steps to retain some of their forest lands in public ownership. The growth of this feeling was due to a fear that the cutting of the forests under private ownership menaced the nation with a dearth of forest cover and material. During the administrations of Presidents Harrison, Cleveland, and Theodore Roosevelt, Congress, by various enactments, granted authority whereby Federal forest reservation areas were set aside. These reservations aggregated 185,000,000 acres of land, of which about 21,000,000 are in Alaska. Within the boundaries of these reservations there is much land privately patented at a prior period, and not all of the public land is tree-bearing. Some of it is meadow and swamp, some is pasture and range, but the net area of forest land in the 151 national forests is approximately 100,000,000 acres. The original forest reservations created from the public domain were necessarily almost all in the Rocky Mountain and Pacific Coast regions. Since 1911, under what is known as the Week's Act of Congress, and later amendments, the Government has been building up national forests in the Great Lakes states and the Appalachian regions, and these purchases are being extended to all Eastern and Southern forest states. It is contemplated ultimately to acquire at least 8,000,000 acres in this manner, of which about 2,000,000 already have been purchased. Forest enthusiasts would have the Federal Government acquire 40,000,000 acres altogether east of the Mississippi River, on the theory that economic forestry will be so long delayed that public interest requires forest conservation and regeneration to be largely a public enterprise. The national forests hold about one fifth of the present forest land of the United States, and approximately one third of the total of 2,500,000,000,000 feet of standing saw timber.

Purpose of the national forests. The national forests are quite commonly confused with the national parks. They are not even administratively related and their primary purposes are divergent. National forests are administered by the Forest Service of the Department of Agriculture, whereas the national parks are under the jurisdiction of the Department of the Interior. The purpose of the national forests is mainly economic, that of the national parks entirely recreational, educational, and inspirational. The national forests were created to afford a continuous supply of forest products to the American people as well as to

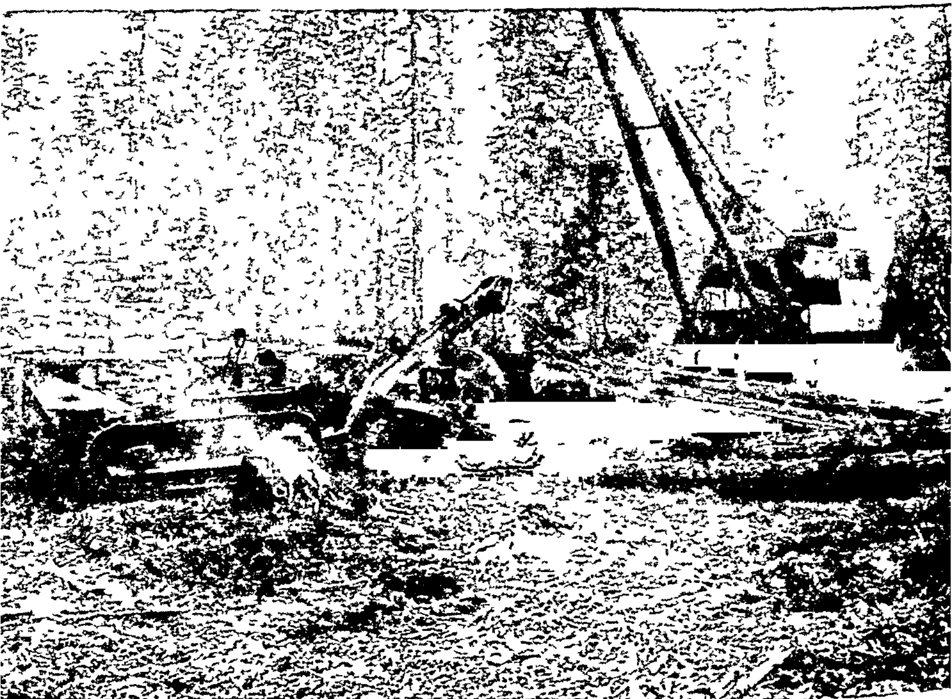
provide the drainage-restraining influence of forest cover for the headwaters of navigable and irrigation streams. The forests, being utilitarian, are not treated as parks, but as sources of economic material. The cutting of timber in the national forests, however, is under extremely conservative restrictions designed to insure the perpetuation of the forests notwithstanding the cutting of trees. The Government does not, (except in the case of Indian Reservation forests, which belong neither to the parks nor to the forests) manufacture lumber. It sells ripe timber subject to its cutting regulations to lumber manufacturers on long-time contracts. The amounts of lumber now yielded annually by the national forests (containing about one third of the remaining timber) is about 1,000,000,000 feet, or perhaps one thirty-fifth of the entire cut of the country; if necessity arises, the yield of the Government forests can be increased to 6,000,000,000 feet a year without impairing the forests. In addition to the national forests, there are some millions of acres of unreserved Federal domain state and municipal forests, which, however, have as yet but little commercial significance. Of private timberland farmers own 160,000,000 acres, and commercial interests about 250,000,000.

Logging and Transport

Early logging. The methods of logging—that is, of felling the trees and removing their utilizable sections or logs from the forests to the mills —are radically different now from what they were as late as 50 years ago. The same is true of the transportation of the logs from forest to mill. Fifty years ago practically all of the tree felling and log cutting in the North took place during the winter months, when snow and cold permitted the formation of ice roads, over which teams of horses or oxen drew sleds loaded with logs, which, except in the case of occasional small local mills, were yarded and skidded on the banks of streams flowing through the forests. The trees were felled entirely by hand and the individual logs were pulled by horses or oxen over the ground to the ice road, where they were loaded on the sleds.

Modern logging methods. With some exceptions caused by the nature of the terrain or the smallness of the lumbering enterprise, the horse and ox have virtually disappeared from the modern logging scene. This change began with the development of the heavy timber regions of the Pacific Northwest. Logging, except for the felling of the trees, which is still almost entirely handworked with ax and saw, is now conducted by machinery. The logs, after being "bucked" into various lengths from the fallen tree, are commonly conveyed to the logging railroad, the highway, or the waterway by means of long cables and by tractors and trucks. Cable logging is of two kinds, the high lead and the low lead. The latter consists of the operation of a low-line wire cable wound over a drum, operated by a stationary steam engine. Strings of logs are attached to the cable and drawn along skid roads or chutes to the engine, where they are parked for transportation to the mill. Sometimes single

logs are dragged in over the ground The high-lead cable process consists of the operation of the log-pulling cable from block and tackle at the top of a tall spar. A trolley cable reaches from this spar to another one placed 1,000 or 1,500 feet away in the forest. As the trees are felled and the logs are bucked, the logs are picked up by suitable tackle and drawn partly on the ground and partly through the air to the single spar. The outer spar is shifted from time to time until all the suitable trees within the radius of the cable have been removed.



Courtesy, Red River Lumber Company

Fig. 1. Steam locomotive log loader, and Diesel tractor invade the forest

In tractor logging, the power tractor has been substituted for the horse and ox of former times and the logs are dragged by the tractors to the loading places. (This is shown in the illustration above, Fig. 1.) Especially adapted and powerful automobile trucks are also used to some extent to pick up the logs as they lie in the forests.

Carrying the logs to the mill. The logs, having been yarded, or banked, at suitable points, are transported to the mills in several ways Transport by floating single logs or rafts on lakes and rivers has greatly declined Most logging transport today is by portable logging railroads, of which there are about 30,000 miles in the United States. Some logging railways have been several hundred miles in length, although such long lines usually are also common carriers. Both steam and electric loco-

motives are used on logging railways. The lateral branches are continuously shifted and relocated as the cutting of the standing timber progresses. Extensive use is also made of the standard railway systems for transport of logs; in that case the loaded trucks are usually taken over from the logging railways. Logs are sometimes hauled several hundred miles on the standard common-carrier railroads.

With the development of better roads and with the greater importance of lumbering operations on lands which have been previously cut over, the automobile truck has become an important factor in transporting the logs from farm lots and other small holdings to the mills. On the Pacific Coast logs are still moved, to a considerable extent, singly or in rafts in protected waters; and enormous rafts, containing as high as 7,000,000 or 8,000,000 feet of logs, are towed on the ocean from the Queen Charlotte Islands in British Columbia to San Diego in the South.

Grading and Inspection

Wood is a natural product which is converted into lumber by sawing into parts. Its natural composition is not altered thereby. It is therefore impossible to classify by quality the lumber of even one species with the precision which applies to synthetic products. Nature never makes any tree exactly like another. Nevertheless, there are criteria for putting lumber into different quality classes or grades, aside from the grouping by species. These grades are determined by the degree in which the particular piece of lumber approximates absence of defects and blemishes. A defect is defined as any irregularity from the accepted standard of perfection which may lower strength, durability, or utility values of the lumber. A blemish is any abnormality affecting appearance.

Classification of lumber. Lumber is classified according to quality, form, finish, and degree of manufacture. The softwood lumbers are now generally manufactured and sold on the basis of species, classification, nomenclature, basic grades, seasoning standards, sizes, uniform workings, description, measurement, tally, shipping provisions, grade-marking tally cards, and inspection in accordance with American Lumber Standards. These standards were worked out by all industrial and commercial groups and professions interested in lumber, under the auspices of the United States Department of Commerce and with the advice of the United States Forest Service, and are published by the Department of Commerce as "Simplified Practice Recommendation R16-29." They are the basis of the grading and inspection rules of all the principal associations of softwood lumber manufacturers. Hardwood grading rules are still nonofficial, since they are only under the authority and administration of the National Hardwood Lumber Association; they are nevertheless well established and administered.

Softwood classification. Softwood lumber is classified, according to use, as yard lumber; structural material; factory, or shop, lumber. Yard lumber is less than 5 inches in thickness and is used for general building

purposes. Factory, or shop, lumber is used for the manufacture of industrial products. Structural material, or timbers, is more than 5 inches in thickness and width. The grading of yard lumber is based upon the entire piece; that of structural lumber upon the strength and use of the entire piece. Factory lumber, since it is intended for remanufacture, is graded according to the proportion of the area which will yield acceptable cuttings In respect to size, yard lumber is further classified as strips, boards, dimension, planks, scantlings, and heavy joists.

With regard to the degree of manufacture lumber is classified as rough, surfaced, and worked. There are three groups of the last: (1) matched to make a tongue-and-groove joint; (2) ship-lapped to make a close rabbeted or lapped joint; (3) patterned lumber—that is, worked to a patterned or molded form.

Yard lumber is divided according to quality or grade into select and common lumber; the former is subgraded as A, B, C, D; and the latter, as Numbers 1, 2, 3, 4, and 5.

Grading of lumber. Lumber is ordinarily graded by graders or inspectors in the employ of each mill, according to the rules of its association, but their work is checked and reviewed by inspectors in the employ of the regional association of lumber manufacturers to which the mill belongs. The association's inspectors always make the reinspection in case of dispute. Manufacturers who do not belong to associations may enjoy their inspection service on a fee basis.

Grade-marking. A corollary of lumber grading is grade-marking, which is now generally available, upon request, from mills following American Lumber Standards. Many of these mills also apply their own trade-marks and the guaranty trade-mark, the "Tree-Mark," of the National Lumber Manufacturers Association, which is a federation of regional associations. Such lumber may be safely bought without inspection by the purchaser.

Before the general adoption of grades, backed by trusted inspection, the lumber industry was in commercial chaos. There were some 29 different grading systems in use, many of them with little or no standing.

The Lumber Manufacturing Plant

The sawmills as a rule are located in or near their forests, rather than in a few centers. The principal lumber manufacturing city of America is now Tacoma, Washington, with Portland, Oregon, ranking second. In the South, among the principal sawmill towns are Bogalusa, Louisiana; Shreveport, Louisiana; Crossett, Arkansas; Meridian and Laurel, Mississippi.

All large permanent sawmill plants have a lumber mill proper and a planing mill. The latter further manufactures the product of the former. Between the original sawing and the secondary manufacture comes the seasoning or drying step. Lumber that is not to have any preparation other than rough sawing may be shipped green, but is usually dried, either by exposure to the air or by passage through a kiln. The sawmill

structure is usually of the single-story shed or factory type with gabled roof, and is of huge proportions in the mills of large capacity.

Logs to lumber. The sawmill, if of any size, is usually built on the banks of a river, lake, or artificial pond, in which the floatable softwood logs are stored from the time of their arrival until they go to the saw. Water protects the logs and makes it easy to move them in any direction. The logs are hauled up from wet or dry storage to the sawing floor of the mill by various methods, chiefly those of the jack and bull endless chains, and are washed by streams of water while on the incline. If very long, the logs are cross-sawed in the pond or after arriving at the sawing floor. They are then thrown onto the log deck, whence they are delivered to the log carriage. The carriage, moving rapidly backward and forward on rails, holds, carries, and drives the log against the saw. It is equipped with machinery for the power handling of the logs, is operated by men riding on it, and is directed by the head sawyer from his station at the headsaw. The headsaw in all large mills is usually a band saw. From the headsaw the boards may go directly by conveyors to the trimming and edging saws; or the squared logs (cants) may go from the headsaw to a gang saw, which cuts the cant into a number of boards at one operation. Smaller mills use a circular headsaw instead of a band saw. Sometimes the resawing of cants is done by band saws. The edge saw squares the edges of the lumber, and the trimmer does likewise for the ends and at the same time makes the boards into standard length. Both trimmers and edgers are circular saws. From the trimmers the boards flow on conveyors to and along the sorting or grading table. Throughout the processes very little hard manual work, except that of a guiding and directing nature, is used. From the sorting table the lumber is conveyed by cars or trucks to the drying piles or the kilns. The tendency is more and more to kiln-dry lumber by steam heat.

Certain classes of building lumber are planed, tongued, and grooved, and are converted into flooring, siding, moldings, or otherwise further manufactured in the planing mills operated in conjunction with the sawmills. After leaving the planing mill, finished lumber goes directly into waiting cars or trucks or is conveyed to storage.

Motive power of the mill. The capacity of a mill is governed by the number of head, or breakdown, saws, as the capacity of one band saw is hardly more than 50,000 feet a working day. A necessary but regrettable feature of all sawmill plants, until recent years, has been the great cylindrical tower in which was burned all refuse that could not be used for fuel or other by-products. Most sawmills supply their own primary power (steam) from sawdust and other waste materials. Often they have a surplus of fuel, and sometimes of electric power, for sale. Power is now commonly applied through electrical machinery in the larger mills. Sawmills rarely purchase electric power, as the abundance of incidental fuel makes it more economical for them to generate their own steam and electricity.

Products of the lumber mill. The rough-sawed products of lumber mills comprise timbers, dimension (intermediate between boards and

timbers), boards, strips, laths, and sometimes shingles, although shingles are more commonly produced in independent shingle mills. Boards are lumber less than 2 inches thick and 8 inches or over in width. They are made by both hardwood and softwood mills and comprise the larger part of the output. Strips are boards less than 8 inches wide. Dimension is lumber that is from 2 to 5 inches thick and of any width. It consists of planks, scantlings, and heavy joists, according to size. Timbers are 5 inches or larger in least dimension, and are chiefly made of softwood.

Important dressed products of the saw and planing mill are: finishing lumber, flooring. drop and bevel siding, ceiling, and partitions. Lumber mills may also primarily produce veneer, both rotary-cut and sawed: and plywood, which is laminated veneer. However, a mill making only veneer and plywood is not ordinarily classed as a lumber mill.

Standard lumber sizes are nominal; in other words, they are based on rough-sawed lumber, before allowing for sawing variation, shrinkage, and dressing or surfacing. Thus, a standard inch-board, nominally of 8 inches width, is actually $^{25}\!/_{32}$ of an inch in thickness and $7\frac{1}{4}$ inches wide.

Broadly speaking, hardwood lumber is but little used in the framing of buildings. Finished products such as flooring, ceiling, siding, casing, baseboards, and molding are mainly made from softwoods. Hardwood is extensively used for floors and paneling, but it mostly goes to the woodworking industries for remanufacture. In hardwoods the phrase "dimension stock" applies to lumber cut for certain specified remanufacture uses.

By-products of the lumber mill. Box shooks are frequently a by-product of lumber mills, and are usually made by softwood mills. Sawdust has a certain market, although it is mostly used for fuel at the mill. In some mills the waste slabs, trimmings, edgings, and other refuse pieces are "hogged" into small particles, which are sold for steam fuel. The refuse of sawmills is coming to be the raw material of mills which produce pulp and paper, composition boards, and insulating material; and such mills are sometimes auxiliary to the sawmill proper. In the future sawmills and industries that convert wood will be more and more integrated. (Wood waste is susceptible to extensive chemical conversion, being convertible into about 200 products. but the sawmills themselves do virtually nothing in this line.) The 60 or 70 industries which use lumber as their raw material make from it some 4,000 different products. Other mechanical by-products are fence pickets, stakes, and plugs for spikeholes in railway ties. Sawed crossties are both an original and a by-product of the lumber mill.

The lumber industry may be credited to some extent with some products; either primary or secondary, which are now sawed, such as hewed crossties, split staves, shakes, poles, posts, mine props, acid wood, pulpwood, and fuel wood; most of its fuel wood, however, is made from sawmill waste. The United States Census limits "lumber" to sawed wood which is reported in board-feet measure, but the popular conception is considerably wider.

Specialty products. Either by special mills or as by-products of regular lumber mills, the lumber industry produces, in addition to items mentioned above, specialized products for further manufacture—such as sash and door stock, cooperage stock, wood billets, wood blanks, spool wood, last blocks, mangle blocks, roller blocks, shuttle blocks, handle stock, toothpick wood, match wood, and so forth. Mills which produce these specialties primarily are not spoken of as lumber mills, but have specified appellations.

Marketing Logs and Lumber

Marketing logs. The major part of the logs consumed by lumber mills in the United States comes from the forests owned by the lumber companies, and the logging is really a part of the sawmill operation. In such cases marketing is not involved. There are, however, especially in the Pacific Northwest, separate logging companies, which cut logs from their own lands or by right of standing-timber purchase, and sell them to mills which may be with or without timber of their own. Usually these logging companies or contractors operate under advance contracts with the mills. Owners of small areas of timber and farmers having woodlots may sell the trees on the stump to sawmills, the mills attending to the logging, or they may cut logs on contract or take a chance on selling them to buyers for the mills. The extension of good roads and the introduction of the motor truck have greatly widened the areas from which mills may collect logs. These improvements have resulted in a considerable revival of sawmilling, usually by portable mills, in regions which had been abandoned by the large mills after the original cutting.

Marketing lumber. Some mills market all or part of their product directly to the ultimate consumer through their own chains of retail yards. Others deal entirely with retailers, either as chain or line yards or independents. There are about 25,000 retail lumber units in the United States, whose business represents about 4 per cent of the entire volume of retail merchandising in this country, the equivalent to $2,000,000,000. Not all of this, however, represents lumber.

A large part of the lumber is sold by the mills to wholesalers, of whom there are about 3,000. As a general rule all yard lumber reaches the consumer through the retailer, whether intermediately handled by a wholesaler or not. There is also a distinct class of jobbers. Industrial lumber is not required by trade practices to go through the retailer. The larger mills usually have district or traveling salesmen, who call on the wood-using industries, wholesalers, and retailers. Wholesalers sometimes control the entire output of a group of small mills, in some cases even financing them. Again, a group of mills may entrust their selling to a sales agency, which may be entirely under their control.

Export sales. Export lumber amounts to about 2,000,000,000 feet annually. It is partly sold through export companies, backed by the mills, under the Edge-Pomerene Act. In other cases individual mills have their foreign agents in different countries. These agents are inde-

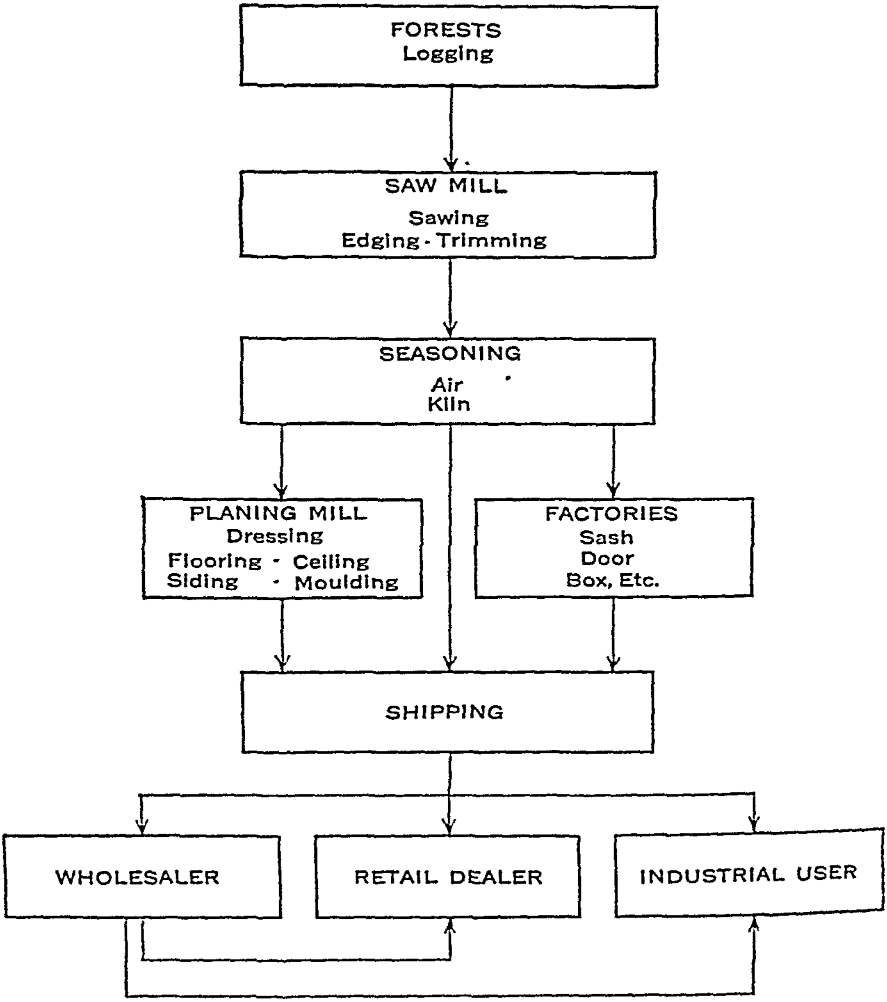


Fig. 2. The flow of lumber from the forest to the consumer.

pendent brokers and merchants. Foreign buyers not infrequently come to this country to place their orders.

Competition. Competition in selling lumber is disastrously keen, owing to the large number of mills, wholesalers, and retailers. Control of production is difficult and is menaced by the antitrust laws. The chaotic condition that results has greatly impaired the prosperity of the industry, even in "good times," and is now receiving serious attention, with a view to correction.

A step toward improvement was the creation in December, 1930, of the United States Timber Conservation Board, appointed by the President, to study the problem of conservative production. The precarious market for lumber leads to much waste of the timber resources of the country.

Associations. In a measure, internal competition in the lumber industry is greatly sharpened by the effects of competition with other materials, which aggressively seek to displace lumber. This competition has led the various regional or species associations of manufacturers to organize trade extension departments, which seek to "promote" their particular products in general and to discourage the use of substitutes.

Methods of Financing

The lumber industry participates to but a limited extent in national corporation financing. Only one or two companies are listed on the New York Stock Exchange. Such financing as has been done through bond issues is mainly through specialized timber investment-banking houses. The industry has, on the whole, built up its own capital out of the business as it has grown, and its corporations are close rather than public. Stock is not widely diffused and, in the case of most companies, is held in a few hands On the whole, it is a home-owned industry. The property of the lumber companies is mainly their timber, and the financing of timber owning is not easy. Because of the nature of its basic financing many of the companies of the industry are unduly dependent upon bank financing. The larger companies supplement the ordinary financing of their local banks by utilization of banks in New York, Chicago, San Francisco, New Orleans, Minneapolis, and other central cities.

Economic Significance

It is not simple to separate the lumber industry from the general group of forest industries; just where it begins and others end is indeterminable Neither in the woods nor in manufacture is there a plain boundary. What the United States Census calls the "timber-products and lumber industry," which embraces establishments operating logging camps, straight sawmills, lath mills, shingle mills, cooperage stock and veneer mills, and planing mills operated in conjunction with sawmills, had a production, in 1937, valued at $848,481,000. The total production of lumber proper was placed at 25,997,000,000 board feet, valued at approximately $630,000,000. The secondary industries—those that use wood as their raw materials—bring the total of the forest-industries products, not including pulp and paper, to $2,440,000,000, according to the Census of 1937. Lumber- and timber-products industries employ 323,928 wage earners; and all the forest industries, as defined above, 725,221, in addition to many thousands of salaried employees.

There is scarcely any industry that is not dependent upon wood, directly or incidentally. It has been called "the indispensable material of civilization." Besides its industrial uses, lumber is of enormous significance in the housing and building industries, since it is either the primary or an auxiliary material in almost every edifice. Of the more than 31,000,000 dwellings in the United States, 25,000,000 are constructed wholly or principally of wood; in addition, it constitutes most of the

world's household and office furniture. As an instrumentality of construction it figures in all buildings, the railroads rest on its crossties, its poles carry the telephone and telegraph wires, and it is extensively used in the building of the smaller boats.

The capital directly involved in the lumber industry in its narrower sense is estimated at $3,000,000,000 minimum and $8,000,000,000 maximum, with the total of all the forest industries, primary and secondary, taking the latter figure up to $12,000,000,000.

Important legislation. The lumber industry is subject to the usual industrial legislation but suffers particularly from the unjust incidence of real-property taxation and the antitrust laws. Annual assessments and collection of taxes on standing timber as part of the land make timber carrying charges oppressive. This stimulates overcutting and discourages reforestation. It sometimes happens that the sum of annual taxes absorbs the value of the increment of a growing forest. The industry believes that the annual tax should be wholly on the value of the land apart from the timber, and that the latter should be subject to a yield tax when cut.

The antitrust laws, preventing restrictive agreements, make for overproduction, reduce or wipe out profits, and discourage programs of continuous-yield management of forests. It is hoped that the work of the Timber Conservation Board will lead to amelioration of taxation and other oppressive legislation. The lumber industry benefits from the Forest Products Laboratory of the United States Forest Service and the Lumber Division of the Department of Commerce.

Future of the Industry

The conviction is growing in the lumber industry that its future prosperity depends much upon carrying manufacture as far as possible, thus getting away from the low-price level which is almost universally associated with basic materials. This will involve horizontal and perpendicular integration and will extend the industry into the realm of chemical manufacture. Lumber mills, pulp and paper mills, and the various mills of secondary manufacture will be united in a single ownership. Wood, it is thought, will come more and more to be looked upon as analogous to mineral ores as a material for conversion into other substances, from which finished goods will be made. In other words, the forests will be considered producers of lignin and cellulose, and the natural form in which those materials appear will be less and less directly used. Under such utilization, forests may be cropped several times in a generation, and yield a much larger total of industrial material than at present. In view of the 500,000,000 acres of forest land in the United States, there is no fear of a general wood shortage. The present supply of standing saw timber is estimated at 2,000,000,000,000 feet—enough to last for 60 years at the present rate of consumption, which will probably decline. Reforestation and sustained-yield management of private forests are certain if economic conditions make them profitable.

The future may see a decline in the use of lumber, as it is now known, but the prospect is that forest utilization will, eventually, augment. Owing to the fact that wood is replaceable, growable, it will be called upon more and more to supplement the exhaustible materials, the minerals, as the pinch of scarcity begins to be felt in them—a period that, for some, is not remote.

6

The Pulp and Paper Industry

In 1940 the paper industry celebrated the 250th anniversary of the establishment of the first paper mill in the United States. Since 1690 the industry has grown steadily, and today it ranks high among the first ten American industries. During its two and one-half centuries of growth, the industry has become almost inconceivably complex not only in its technology but also in its economic structure.

The importance of the industry in modern economy is rarely appreciated by the layman. This lack of appreciation is not surprising because the layman purchases but little paper as such. And this in spite of the fact that he is literally wrapped in paper from birth to death! The per capita use of paper in the United States, for instance, now averages well over 250 pounds a year. Practically all of it comes to the ultimate consumer as an adjunct of some other product or of some service. Paper is a newspaper, it is a box, it is a towel or a napkin, or it is a thousand or more other articles which are delivered to the consumer but for which he rarely ever receives a bill.

What paper is. Paper is a product composed of vegetable fibers oriented and matted together in the form of sheets of varying thicknesses, which possess flexibility and strength and which can be cut or remanufactured into an almost infinite number of sizes, shapes, and articles. Paper is both a raw material and a finished product. In production it is well adapted on the one hand to the processes of mass production, and on the other hand to highly specialized manufacture.

The 5,000 or more grades or kinds of paper fall into two broad classifications: those which are used for cultural purposes such as printing and writing; and those which are used for mechanical or physical purposes such as wrapping, packaging, sheathing, and roofing. The latter class is of comparatively recent development and it is growing rapidly every year as paper and paper products are substituted for other materials or products. The cultural uses reach back to the beginning of the Christian era; it was the demand for cultural purposes that provided the urge for the invention of paper.

Distribution, Capitalization and Sales of the Industry

The industry which produces paper in the United States is widely distributed; *some* paper is manufactured in each of 37 states. The industry is located both in the forested states from which adequate wood can be obtained for the manufacture of wood pulp, the principal fibrous material used in paper manufacture, and in industrial states to which wood pulp is shipped and from which fibrous materials can be collected in the form of waste paper, rags, and other secondary products.

Well over $2,000,000,000 are invested in the primary industry in the United States and nearly another billion is invested in the secondary industries which remanufacture or convert paper into paper products. Some 250,000 workers are employed over-all in the industry, slightly more than one-half in primary production. In addition, perhaps an equal number of workers is employed in the production and collection of raw materials for use in the industry, many of whom are farmers who supplement their agricultural income by the production of pulpwood during slack seasons.

The annual value of the industry's primary products ranges well over $1,500,000,000. The value of the converted products reaches nearly a billion. A substantial and rapidly growing additional value accrues to the industry from the sale of wood pulp to other industries for the manufacture of plastics, rayon, explosives, and for a host of small uses.

History of Paper Manufacture

Invented at the beginning of the Christian era, handed down from generation to generation, passed on from race to race, the art of paper-making has come to the modern world essentially unchanged in basic principle. During 20 centuries man has refined original processes, standardized products, and quickened production, but many of the products now made by machinery and at great speed are not unlike those few sheets laboriously turned out by the first Chinese paper-maker. Yet paper manufacture has never been static; rather it has always been, as it is now, in a state of progress. It has flowed with humanity down through the ages, and upon its products the stream of history itself is recorded.

The search for a recording medium. Man has struggled long to climb the ladder of progress, and civilizations had waxed and waned before real paper was discovered. Previously, baked clay tablets, smooth stone surfaces, metal plates, the bark of trees, wax tablets, and dried skins had been tried and sometimes used extensively before papyrus was generally adopted as the best writing material by the Greco-Roman world. The discovery of papyrus is shrouded in the distant past; well-preserved rolls bearing the partial records of ancient Egypt have been found in the tombs of the earliest Pharaohs. Papyrus reached its greatest importance in the Hellenistic Period following the death of

Alexander the Great. Along with parchment it continued to serve the needs of man after the fall of Rome until it was finally supplanted by real paper introduced from the East in 900 A.D. Yet it left its imprint for all time; the modern word "paper" is derived from the Greek word "papyros." Oddly enough, papyrus was not paper; it was made of stalks of a sedge thinly sliced, lapped together, and pressed into sheets.

The invention of paper. The original invention of paper is credited to Tsai Lun, who, it is recorded, reported the discovery of processes and techniques to the Chinese Emperor in 105 A.D. Silk and bamboo, previously used as recording media in China, were unsatisfactory, and Tsai Lun undertook investigations to find new materials. He first experimented with the inner bark of the mulberry tree, which he successfully converted into paper by first reducing it to a fibrous condition and subsequently matting the fibers into sheets. Later he extended his research to rags, hemp, and fish nets and found rags the most satisfactory. From then until the middle of the nineteenth century rags remained the chief paper-making material, and they are still used today in fine papers and in papers of special characteristics.

The use of the newly discovered material for recording purposes gradually spread throughout China. The art of paper-making was established in Arabia in the early part of the eighth century when the Arabs captured several Chinese paper-makers in Russian Turkestan. Commanded to continue their art, the prisoners successfully taught it to the Moors at Samarkand. The art spread quickly to other cities in the Near East, becoming established in Bagdad in 795. Paper-making soon became an integral part of the Moorish culture which was to contribute so much to the rise of western civilization.

Early paper manufacture in Europe. Paper was unknown in western Europe until the Moorish invasion in the eighth century. Whether the Moors actually brought paper during the invasion or whether it was brought after the conquest by commercial travelers from the Moorish colonies in northern Africa are moot questions among historians. At any rate, history records paper mills at Xativa, Spain, and Fabriano, Italy in 1150, in France in 1189, in Germany in 1291, and in England in 1330.

While the use of paper remained confined to the upper classes of society, the output of the few mills was sufficient to meet the modest requirements. At the beginning of the Renaissance, however, the whole tempo of social and commercial life quickened. Education, stimulated by the development of printing, sifted downward from the upper classes and cultural standards rose rapidly. The intangible desire of the few for information and news rapidly became the vital necessity of the many. The demands of a growing civilization taxed the mills to the utmost, and the inadequate supply of rags soon limited the expansion of the industry. Henceforth until the nineteenth century, the inadequacy of the rag supply was a constantly more pressing problem.

Invention of paper-making machinery. During the Industrial Revolution the crafts, among them the art of paper-making, burst from the stagnation of the Middle Ages. Machines appeared and power came

into general industrial use. The paper industry, like all others, felt the changes. In about 1750, in the Netherlands, the forerunner of the modern *Hollander*, a beating engine, was invented for tearing rags apart. In 1797, Louis Robert, a French workman, visualized the possibilities of matting fibers by machinery. A few years later in England his imperfect machine was improved by Henry and Sealy Fourdrinier, who constructed the first paper machine in 1803. Its successful operation revolutionized the whole industry, for it provided a means of making paper rapidly, continuously, and cheaply. The laborious and slow hand methods of making one sheet at a time gradually gave way to machine methods.

Discovery of the wood pulp processes. The perfection of power-driven machinery emphasized the inadequacy of the rag supply and stimulated research in raw materials. Early investigations of the use of other materials were carried on in Germany, France, and England and some interesting treatises were published. These treatises, however, suggested rather than proved the feasibility of using other substances. The first important publication in English was a research report by Machias Hoops shortly after 1800, which contained samples of paper made from straw, leaves, wood, and several other vegetable materials. But practical results were not obtained until 1840, when Keller invented the wood grinder in Germany.

A grinder was set up and operated successfully in 1854. Although differing widely from rag pulp in strength and quality, the resulting pulp gradually found use in mixtures with rag pulp in the production of papers for which permanency was not required. Mechanical wood pulp, or groundwood, as the new pulp was called, did not replace rags; it was simply a substitute for a portion of the rag content in many papers. Rags still remained essential to the industry.

The next outstanding contribution was made in 1867, when Tilghman's work in the United States laid the foundation for the subsequent development of the sulphite pulping process. In his chemical research Tilghman had noticed that sulphurous acid dissolved the ligneous constituents of wood, leaving a residue of cellulose fibers. He found these fibers suitable for paper manufacture, but his efforts to perfect a commercial process were unsuccessful. Later, however, Ekman carried the work further in Sweden and developed a commercial process. At the same time Mitscherlich was working along similar lines in Germany, and Ritter and Kellner were also experimenting in Austria. These three adaptations of Tilghman's work proved successful and all were in operation by 1882.

In addition to the sulphite and mechanical processes of making wood pulp, three other processes are now recognized, all using sodium as a base: the sulphate process discovered by Dahl in 1884; the soda process actually tried in 1851 but not found commercially practicable until much later; and the various semi-chemical and neutral processes, some of which have been used with more or less success and some of which are now in the development stage. All of these processes are primarily designed to pulp wood.

The improvements of the chemical processes and the rapid establish-

ment of pulp mills throughout the world marked a fundamental change in the paper industry. No longer were paper manufacturers handicapped by an insufficiency of raw material. The way was open for rapid expansion, and manufacturers in those countries which possessed adequate supplies of suitable pulpwoods initiated expansion programs upon which the world industry rests today.

Paper Manufacture in the United States

The manufacture of paper in the United States began in 1690, when the Rittenhouse mill was erected near Germantown, Pennsylvania. Promoted largely by William Bradford, this mill was successfully operated by William Rittenhouse, a paper-maker by training. It is probable that a second mill was built at Elizabethtown, New Jersey, in 1728. In the same year a mill was erected in Delaware County, Pennsylvania, by Thomas Wilcox, in which writing, printing, bank-note, and other types of papers were made. The establishment of the industry in New England probably also dates from 1728, when a group of notable figures in colonial history obtained permission to build a mill in Massachusetts. The first New York mill was erected in 1768, at Hempstead, Long Island, at what is now the town of Roslyn.

At the time of the Revolution there were many paper mills in the colonies. Nearly all of them were small two-vat affairs which required no more than ten men to operate. All operations except beating were conducted by hand. Sheets were made by dipping a mold into a vat of "half stuff," the pulp in water suspension. The water was removed by hand presses and by drying on poles. About $10,000 capital properly employed was sufficient for the erection of a mill and for meeting the usual running expenses—a figure that is insignificant compared with present investments. Rags were obtained locally. Although the difficulty of obtaining them in sufficient quantities handicapped the early paper-makers, most of the paper needs were met domestically in late colonial times. A serious shortage of paper occurred during the Revolutionary War period, but it was comparatively short-lived, as evidenced by Alexander Hamilton's report in 1791 that the "manufacture of paper was most adequate to a national supply."

The erection of paper mills continued during the first decade of the nineteenth century. The first census of manufactures in 1810 reported 179 mills in 17 states, exclusive of Massachusetts, and the total output of the year was probably about 3,000 tons. At this time the domestic supply of rags was particularly inadequate, and imported rags were widely used. Their scarcity and expense stimulated investigations of other materials as a fiber source, but the earlier researches were fruitless.

European competition. In 1815 the growing industry suffered its first serious setback; it was literally swamped by a flood of paper from Europe with which the domestic mills were unable to compete. How disastrous this competition was is shown by the census of 1820, in which but 108 mills were reported in operation as compared with 179 mills 10 years earlier. But the industry soon revived after tariff adjustments in

1822. It then began a steady technical development and a constantly increasing growth which swept it on to greater and greater achievements.

Advent of paper-making machines. The first Fourdrinier paper machine was brought to the United States in 1827 by Henry Barclay to be installed in a mill in Saugerties, New York. In 1830 Phelps and Spafford, of South Windham, Connecticut, undertook the manufacture of Fourdrinier machines. From then on the number of machines increased rapidly. It is said that by 1850 paper machines were used in every mill in the United States except two.

Beginning of the modern paper industry. Up to 1850 both processes and machinery were constantly improved, as evidenced by the rising output trends. But even greater improvement was to come. The thirst for news during the period leading up to and during the Civil War stimulated the consumption of printing papers. The industry strove to keep abreast of the demand. Hampered by the ever-present shortage of rags, it turned to straw, and straw paper for printing and wrapping became general. But rags still dominated the industry; their high prices required equally high prices for paper. The really great strides of the industry were still to come; the modern industry had not yet begun.

The modern industry and the modern varied use of paper began in the eighties, when wood pulp papers appeared. Paper prices soon fell and demand was stimulated. Paper became an everyday article of commerce and available to all. By 1890 a new paper industry had been built up to supply an ever mounting demand. Upon this framework American manufacturers have built an industry that produces more than one-half the world's total output.

In this growth of production and consumption, technical development played a large part. In 1866 the first wood grinder was installed in the United States, and by 1870 8 groundwood mills were reported; 10 years later 42 additional mills used grinders. The greater cheapness and the consistent improvement in quality encouraged greater consumption. The manufacture of sulphite wood pulp, first introduced into the United States in 1882 by Charles S. Wheelwright, reached a practical basis in the nineties and thereafter the number of sulphite mills grew rapidly. Soda pulp mills were erected also. Sulphate pulp did not appear until about 1910; and its importance was not marked until after 1920. Since then its production has increased steadily, and today it leads all other kinds in volume of annual output in the United States.

Regional expansion. Early in its development the modern industry centralized in New England, because there adequate supplies of spruce pulpwood could be obtained. In the nineties the industry expanded to the Lake States, where a rapid growth took place. Until after the First World War these regions produced most of the wood pulp and paper manufactured in the United States. Further expansion in these regions had by then become difficult, for the industry had reached the limit of available spruce pulpwood supplies and was depending more and more upon Canadian spruce pulpwood, which had begun to be imported as early as 1895.

In the first decade of the twentieth century, before methods for pulping other kinds of wood more plentiful in supply in the United States had been developed, wood pulp manufacture expanded rapidly in Canada. Increasing percentages of the output were exported to the United States. After 1920 imports of wood pulp from northern European countries competed not only with domestic production but also with imports from Canada. Moreover, the duty on newsprint paper was removed in 1913, giving Canadian producers new market advantages which were immediately grasped. A tremendous growth in newsprint production occurred, eventually placing Canada in world leadership in this branch of the industry. In the period following 1910 the United States built up a heavy dependence upon outside sources for pulpwood, wood pulp and newsprint paper. Imports of these products reached values which exceeded those of any other single group of industrial products manufactured in substantial quantities in the United States.

Meanwhile the domestic industry was not idle. After intensive research the southern pines proved suitable for the manufacture of sulphate pulp for conversion into wrapping paper and paperboards. Pulping techniques were developed to use western pulpwoods and a rapid expansion in manufacturing facilities in Oregon and Washington began. These developments added substantially to American production, so much so that dependence upon alien sources was reduced in all grades of pulp and paper except in newsprint.

Raw Materials for Paper and Pulp Manufacture

In most papers only the cellulose fibers of plants are used; in some kinds, however, as in newsprint, the fibrous material is used in entirety. The basic principle of paper-making is to separate out the fibers in the raw material, treat them to facilitate their use, and mat them into a sheet on the paper machine. The process of separating the fibers is known as pulping, and that of matting them together is the actual paper-making process.

The materials used in the manufacture of paper may be divided roughly into fibrous, chemical, and manufacturing. The first are made up of pulpwood, straw, rags, jute, and other materials of like nature; they form the main substance of the finished sheet. The more important chemical materials are sulphur, lime, caustic soda, and salt cake used in pulping, and rosin, sulphate of aluminum, clay, and casein in treatment of the pulp and in finishing the sheet. The manufacturing materials consist largely of coal, power, and water.

Fibrous materials. In theory, practically any vegetable material can be used in paper manufacture. In commercial practice, however, those plants are used which are high in cellulose content and which are inexpensive to obtain and to pulp. The length and shape of the fibers vary with the characteristics of the plant and with conditions under which it is grown. In modern paper manufacture a variety of different fibers are required to make the wide range of products in common use.

Long and strong fibers are needed for strength; [illegible] fibers are required for bulk and [illegible]. [illegible] extremes [illegible] different [illegible] the [illegible] requirements.

Fibrous materials for paper manufacture [illegible] according to the part of the plant from which they are derived. Cotton, [illegible] adapted to paper manufacture, [illegible]. Flax, hemp, jute, [illegible] fibers [illegible]. Fibers from stems of plants [illegible] materials [illegible] is used extensively in the United States. [illegible] group, from a quantitative point of view, comes from wood.

Annual plants. Many of the principal characteristics of papers are directly related to the specific qualities inherent in the primary fiber material. Cotton, for instance, available [illegible] textile plants, yields a high percentage of pure cellulose which is used in high-grade papers where strength, permanence, [illegible] are important prerequisites. Low-quality cotton rags, frequently mixed with [illegible] wastes, are used in coarser papers where strength is the principal requirement. Linen, perhaps the best paper-making material, is expensive and difficult to obtain in the United States and its use is confined to extremely high-grade papers. Manila stock is used for extreme strength in papers in which color is relatively unimportant, for it cannot be bleached without impairing its strength. Esparto and other grasses are used in some countries, esparto particularly in Europe where it meets the needs of a soft pulp of excellent color. The use of straw in the United States is now confined almost entirely to the manufacture of strawboard where certain qualities of stiffness are required. Straw is still used in some European countries in the manufacture of other kinds of paper, especially wrapping paper in Holland and Belgium. Bagasse, the waste from sugar manufacture, is used in the manufacture of a well-known insulating board; it has not proved suitable for paper manufacture.

The tendency is toward a more restricted use of all of these materials in the United States. Wood pulps have been improved to meet many of the more exacting requirements of the paper industry, and they are less expensive. Nevertheless, experimentation in the use of annual plants continues, and it is possible that from it the list of fibrous materials which will impart other special characteristics to paper will be increased.

Waste paper. Waste paper is used in increasing quantities in the United States in the manufacture of paperboard and in book papers. It is obtained from the centers of paper consumption and reconverted in mills usually located near the source of waste-paper supply. Normal requirements for paperboard manufacture have reached four million tons or more per year. In book paper the higher qualities of waste paper are

used with mixtures of fresh or virgin pulp, principally sulphite wood pulp. Here the waste paper replaces soda pulp, which is used in virgin sheets. Limited quantities of waste paper of selected grades are used in other papers, but in no case are the requirements particularly important. Between 400,000 and 500,000 tons are used annually in grades other than paperboard.

Pulpwood. Although it is difficult to compare the use of pulpwood with that of other fibrous materials because pulpwood is measured in terms of volume rather than weight, it is generally held that pulpwood comprises about 90 per cent of the primary fibrous material used in paper manufacture. Waste paper is eliminated in this comparison because actually it is wood pulp, but available in a waste form.

The importance of wood as a paper-making material is principally attributable to its relatively low cost Wood is the accumulation of many years growth on a given area of land. It is compact; it is easily handled; it may be cheaply stored; and its pulp yield is relatively high. The total supply of pulpwood in the United States, all kinds considered, is ample for any expected domestic need. In those kinds in which the national supply is inadequate, substitution is occurring and imports from other countries are usually available in greater quantities than are needed. In fact, the demand upon the nation's forests for pulpwood is still less than 10 per cent of the total annual drain.

Pulpwood is composed of sections of the trunks of trees especially prepared for conversion into wood pulp In all countries and in all regions of the United States except the Pacific Northwest, pulpwood consists of short sections ranging from approximately 4 feet in length upward and from 4 to 14 inches in diameter. In the Pacific Northwest logs are cut in the typical power logging operations common in the production of logs for lumber.

Much of the pulpwood produced in the northern states is cut and peeled in the spring months when the bark can be removed by hand tools. Except in the more accessible areas peeled wood, as well as rough wood cut in the late fall, is transported from the woods to the mill or to an intermediate shipping point on snow or ice roads during the following winter. In the Northeast and in Canada much pulpwood is river-driven from the forest to the mill during the high-water periods in early spring Most northern mills carry large stocks of pulpwood to tide them over the relatively long periods between cutting and receipt at the mill.

In the South, climatic conditions are such that pulpwood operations can be carried on continuously, and extensive storage is unnecessary. Pulpwood operations are integrated closely with mill requirements, and the wood passes directly into processing upon receipt at the mill. Most wood in the South is delivered in rough form; the bark is removed at the mill by mechanical equipment.

Far-reaching changes have taken place in the use of pulpwood since the introduction of the wood pulp processes in the 80's. Research has proved the suitability of many other kinds of wood and these are now quantitatively more important in American use than spruce, because of

their greater availability. Figure 1 shows the consumption of pulpwood by the more important kinds since 1899.

The rapidly rising use of pine, principally southern pine, and of hemlock, chiefly western hemlock, illustrates the extent to which regional expansion of the industry has taken place in recent years. The declining use of spruce in the United States must not be considered as an indication that the requirements for wood pulp manufactured from spruce have dropped to the same extent. This is not true. In the absence of extensive supplies of spruce, more and more of the spruce requirements of the United States have been supplied in the form of newsprint paper and

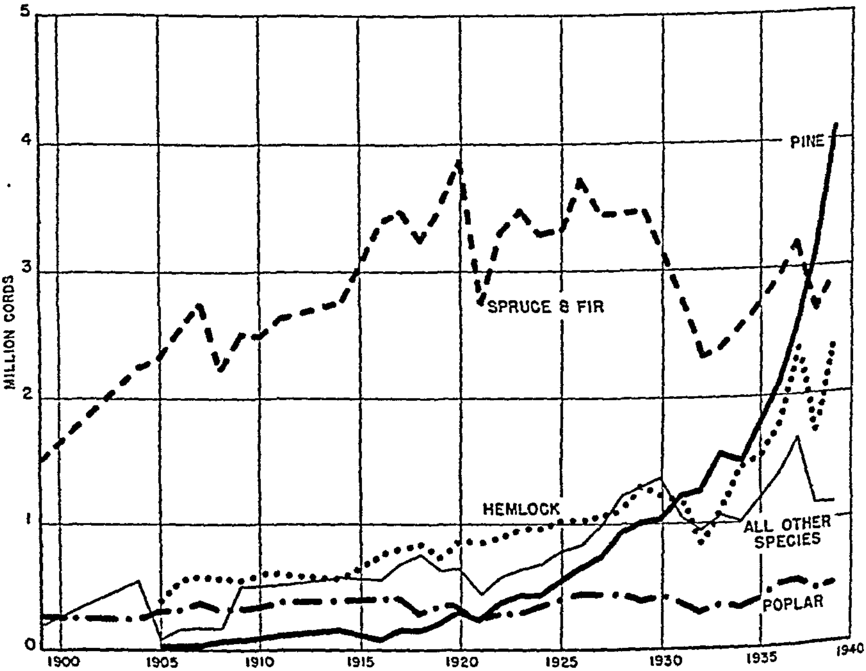


Fig. 1. Consumption of pulpwood in the United States, 1899-1939 Source: Department of Commerce.

wood pulp imported from more northerly located countries where spruce grows more prolifically.

Chemical materials. The chemical materials used in paper manufacture are of two varieties: those used in pulping and those used in pulp treatment and paper finishing. The first group are used simply as tools to separate the fibers of the pulp material; they are not present in the final product. Part of the chemicals in the latter group are lost in the manufacturing process, but some, such as alum, clay, rosin, and casein, are retained in or on the sheet, giving it desirable characteristics As modern technique has developed, the use of chemicals has increased Nowadays many different chemicals are used which formerly were not considered useful. This increase is due not only to the special character-

istics which chemicals give the final product but also to the fact that chemicals facilitate the control and standardization of processes.

With few exceptions, most paper-making chemicals are of domestic origin. Some are well distributed geographically and may be drawn from near-by sources. This is true of lime and limestone. Sulphur, on the other hand, comes wholly from the Louisiana and Texas mines, and its cost, delivered to the pulp mill, is directly proportionate to the transportation charge.

Manufacturing materials. Manufacturing materials have an important bearing upon pulp and paper manufacture and particularly upon mill location. In fact, it is just as important to possess advantages in these as in fibrous materials or even in market accessibility.

Water. In addition to being necessary for boiler feed, water is required in the pulp and paper industry for making chemical solutions needed in the manufacturing processes, for washing out impurities such as spent chemicals and dirt from the pulp, and for conveying the stock throughout the system and upon the paper machine.

The quality of water is important, especially in the production of high-grade papers. This is true in spite of the fact that most pulp and paper mills now have filtering systems and water treatment plants.

Power. The pulp and paper industry is a large user of power. Power is required chiefly for running the paper machine and other equipment. It is needed particularly in grinding wood for the manufacture of newsprint paper; ample and cheap power is as essential to newsprint manufacture as adequate supplies of pulpwood.

The industry is closely identified with hydroelectric power development, for modern practice tends more and more toward electric drive. Many small mills either purchase electric power or generate their own steam power. Yet some small mills, particularly in the Northeast, use water power which is controlled by the company. Wholly owned and operated hydroelectric power stations may be a part of the industrial make-up of the large company, particularly in Canada.

Fuel. Fuel is needed in paper-making, chiefly to generate steam for drying purposes and for cooking the pulp. It is, of course, also used to generate steam power. The fuel requirements are heavy; from one to one and one-half tons of coal, or its equivalent in oil, is required in the production of a ton of paper. Cheap fuel is obviously a necessity for low-cost production. There are wide variations in fuel costs in the industry, dependent, of course, upon transportation charges from coal mines or oil wells. In general, fuel costs are higher at the northern mills as compared with the southern mills, many of which use locally supplied natural gas. Many western mills have been able to reduce their fuel costs by using wood waste from neighboring sawmills.

Labor Requirements

The skill requirements of labor employed in pulp and paper manufacture are relatively high, for the industry is characterized by its large

and highly complicated machines. Labor requirements center in machine operators and in highly skilled maintenance men. Moreover, many processes are controlled entirely by the man in direct charge of the equipment. Some companies still rely upon the judgment of operating men in such matters as cooking and beating time and even in the make-up of the paper-making formula, or "furnish," as it is called. To these companies paper-making is still an art and many of their employees are highly skilled artisans.

The use of unskilled labor in the mill is relatively limited. Such labor varies widely, however, with the type of mill and the efficiency of its design and management. Most labor is male. Female labor is employed for rag-sorting and for counting and finishing sheet paper. Technically trained men are in demand in the industry and are tending to displace the so-called "practical" man in the higher operating positions. Many are employed in research activities in which the industry ranks high among all industries.

There are two important labor organizations in the industry, both of which are American Federation of Labor unions. Efforts have been made by the C. I. O. to organize the industry but without marked success except in some converting industries. Somewhat more than half of the industry's workers are union members. As a rule, union leaders work in harmony with mill executives, and strikes and lockouts are infrequent. Because of the close cooperation between the two A. F. of L. unions, the industry has fortunately been spared jurisdictional disputes.

Manufacturing Processes

The processes by which pulp and paper are made are exceedingly complex, as indicated in Figure 2, which shows in diagrammatic form a flow chart of major materials and processes. The paper-making process falls into five major classifications: manufacture of pulp; pulp preparation; paper-making; finishing of the paper; and the conversion of paper into paper products.

Pulp manufacture. Pulp is manufactured by four major processes which are briefly described below. All of them are used in the production of wood pulp; one, the soda process (or modifications of it) is used to pulp most other fibrous materials. Some progress has been made in the development of other processes, mostly designed for pulping wood. Some of them are being used in specific instances.

Mechanical wood pulp. In the mechanical process, wood pulp is made by grinding wood on a revolving grindstone which tears the fibers apart without significant chemical change. Because the resulting pulp contains practically all of the woody as well as cellulose constituents of the original wood, it is not stable, nor can it be bleached. Its use, therefore, is confined to papers in which permanency and color are not important, such as newsprint, catalog and hanging paper, and certain paperboards. The process is exacting in its wood requirements; relatively soft, nonresinous woods such as spruce, balsam fir, western hemlock and aspen

are usually sought Recently a process has been developed for grinding southern pine, and a newsprint mill making use of this process has been established in Texas.

Sulphite wood pulp In the sulphite process, wood pulp is made by cooking wood chips in an acid liquor, chiefly bisulphite of lime, at fairly

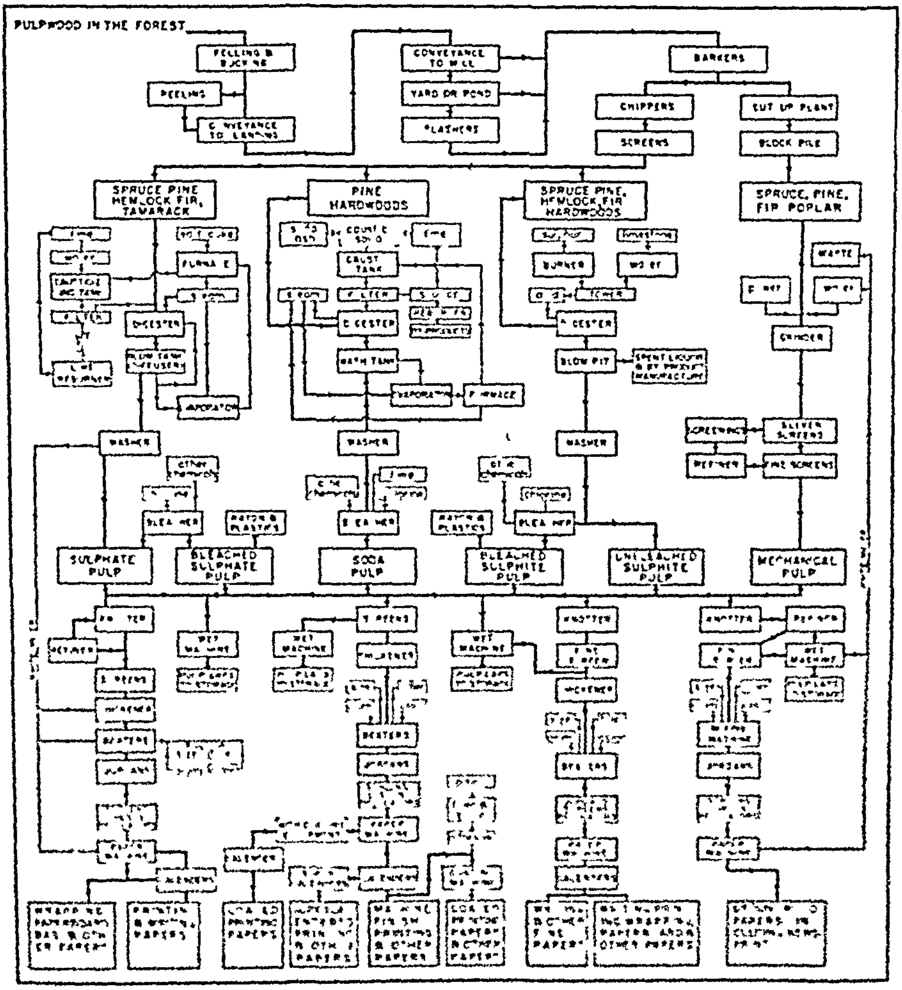


Fig 2 Diagrammatic flow chart of materials and equipment used in the manufacture of wood pulp and paper

high temperatures and pressures In this process, most of the non-cellulose constituents of the wood are removed and the resulting pulp, composed principally of cellulose, is relatively stable Sulphite is used in a wide variety of papers; in unbleached form in newsprint and other groundwood papers, wrapping paper, and food-container boards; and in bleached form in writing, book, tissue and wrapping papers, and in [illegible]

host of specialties. Refined sulphite pulps are desirable for rayon, plastics, lacquers, and many other products, as well as for high-grade paper. Sulphite pulp is also exacting in its wood requirements, for it can be used only with non-resinous woods. Spruce, balsam fir, and western and eastern hemlock are the principal species reduced by this process.

Courtesy, Weyerhaeuser Timber Company

Fig. 3. Sulphite wood pulp digestors in course of construction before housing and before installation of auxiliary equipment.

Soda pulp. In the soda process wood pulp is made by cooking wood chips in caustic soda solutions under conditions similar to those used in the manufacture of sulphite pulp. This process is used principally to pulp the short-fibered hardwoods such as aspen, gum and poplar. It is also used to pulp most materials other than wood. Soda wood pulp is employed chiefly in mixture with sulphite wood pulp in book and other printing papers. It has been replaced in many mills by waste-paper pulp.

Sulphate wood pulp. The sulphate process is a modification of the soda process in which sodium sulphide is substituted for a portion of the caustic soda in the cooking liquor. The presence of the sulphide permits more rapid and uniform pulping of a less drastic nature. The pulp is, therefore, very strong—hence the name "kraft pulp," German for "strong." The sulphate process will pulp any kind of wood; it is used principally, however, to pulp long-fibered woods to obtain strong pulps. It is used in unbleached form in wrapping papers, paperboard, and specialties where strength is necessary and color is unimportant. In bleached form. a relatively recent development, it is applied to the making of food-container boards, file folder stock, wrapping papers, and specialties.

Pulp preparation. The detailed processing of pulp is different for each kind of paper. In general, however, all pulp must be thoroughly washed and screened and it must pass through some sort of beating process to prepare it for use. Pulps for the manufacture of white papers must be bleached. Bleaching is a process of oxidation by means of hypochlorites of calcium and soda.

The beating process consists of circulating pulp between a heavy roll and a bed plate, both of which are provided with blunt steel bars The beating action brushes out the fibers, bruises them into a more or less gelatinous condition, hydrates them, and separates the bundles so that each fiber floats free in water suspension. Much of the difference between grades of paper, other than that inherent in fibrous materials, results from different beating treatments. In the beater many of the other ingredients of paper are added, such as size, dyes, loading materials, and so forth.

In newsprint and kraft wrapping paper and paperboard manufacture, Jordans are used instead of beating engines. They also supplement beating engines in the production of many other grades. Action in the Jordan is somewhat similar to that of beating but not so complete. The advantage in using Jordans is that the flow of pulp is not interrupted.

Paper-making. Paper is made upon two types of paper machines. The most common is the Fourdrinier, named after the manufacturer of the first paper machine.

The Fourdrinier paper machine is actually a series of machines. The pulp in water suspension flows onto a moving wire-screen belt. The water drains through the belt by gravity aided by suction rolls and by capillary action of the supporting table rolls. At the end of the belt it is picked off on a woolen felt, which carries the web of fibers through a series of press rolls, where the web is compressed and additional water is

squeezed out. From the press section, the web passes through a series of heated cast-iron cylinders where it is dried At the end of the cylinders the sheet, which is now completely formed, is calendered by being passed between heavy polished rolls The finished paper is wound upon reels at the end of the machine.

There are two important modifications of the Fourdrinier paper machine which are used principally for light-weight papers. These are known as the Harper and the Yankee machines.

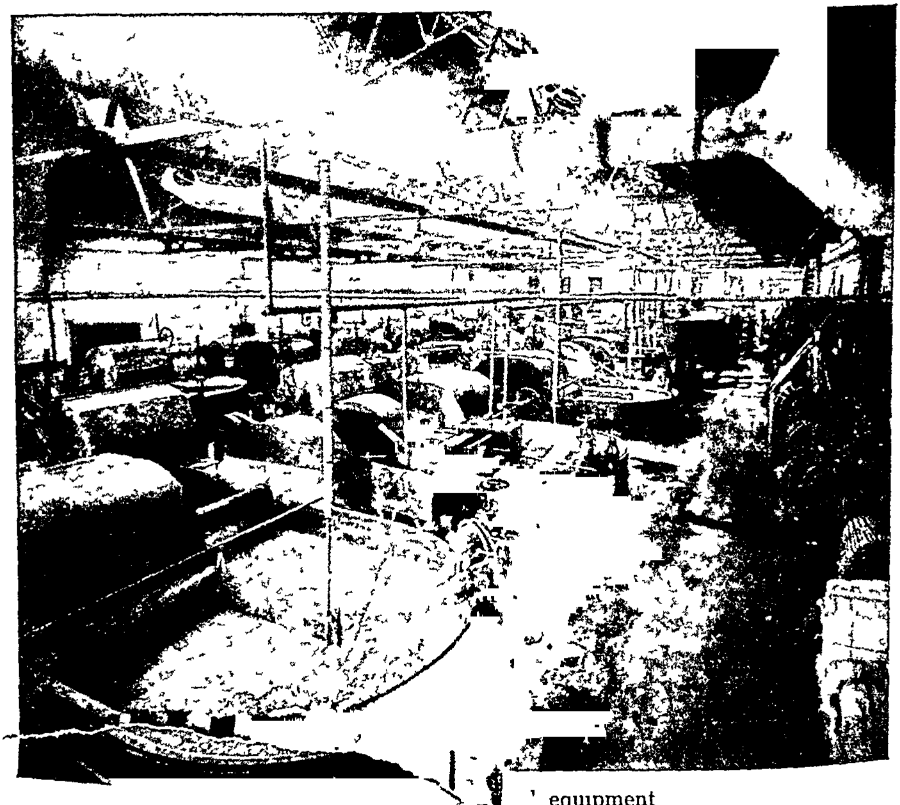


Fig 4 Beater room and [illegible] equipment

The cylinder paper machine differs from the Fourdrinier in the wet or sheet-forming end. Instead of a moving wire-screen belt, cylinders covered with similar material are submerged in vats of pulp in water suspension. The water in passing into the cylinder deposits a film of fiber upon the outer surface. This film is picked off upon a woolen felt as the cylinder revolves.

Many single-cylinder machines were formerly used for the manufacture of light-weight papers. To a large extent these are being replaced in modern operations by Fourdrinier machines. The multicylinder machine—that is, several cylinders operating in a series, each depositing a

film of stock upon the same woolen felt—are used in the manufacture of heavy-weight papers and paperboard. In making such papers, it is possible to use different kinds of stock in the different vats. This practice is advantageous for certain types of paperboard.

Cylinder machines are limited in their speed because of the centrifugal force of the revolving cylinders. They rarely are operated above 400 feet per minute. The limit of speed of the Fourdrinier machine is chiefly its drying capacity. Fourdrinier machines in newsprint and kraft wrapping-paper manufacture operate up to 1,500 feet per minute and some special machines have been designed to operate as high as 2,000 feet per minute. Because of the pressure for production, modern practice tends more and more toward the Fourdrinier machine, even for the manufacture of paperboard. As speeds have been stepped up, machines have been made constantly wider, up to and even exceeding 300 inches.

Both types of machines are driven by synchronous motors which have replaced gear drives formerly used. The synchronization of the motors must be exact—for any difference in speed will break the web of paper which passes through the machine, and in the latter sections this web has no support.

The paper machine is one of the largest machines in industry. It is also one of the most expensive. A modern installation costs in excess of a million dollars.

Paper finishing. Paper comes off the paper machine in large rolls. The reduction of these rolls to the sizes and forms required is accomplished in the finishing room of the paper mill.

In cases where paper is delivered in rolls such as newsprint, printing, and wrapping, the large reels from the paper machines are slit to the proper sizes as they are rewound. These are then wrapped and labeled for shipment. Here the finishing process is relatively simple.

Paper which is sold in the form of sheets must be cut to proper size, and in the case of high-grade paper, each sheet is inspected, counted, and packed. Paper that is sold in accurate sizes must be trimmed after cutting. These processes, although relatively simple, require extensive finishing departments, particularly in book- and writing-paper mills. Most mills use female labor for inspection, sorting, packing in small lots, and in sealing the packages.

The manufacture of paper products. Relatively large percentages of the paper produced in the United States are converted into paper products either in conversion departments connected with the mill or by independent converters.

The number of paper products and the processes employed are altogether too numerous to be described. Several processes, however, fall into two broad classifications; one is the surface treatment such as gumming, coating, embossing, and striping, and the other is cutting, folding, and shaping flat paper into containers and various other products.

The coating of paper as, for instance, the manufacture of coated book paper, is accomplished by the application of coating materials to the

surface of the sheet. Clay, casein, talc and other substances are used. Other surface treatments such as embossing, striping, and ruling are done on machines specially made for the purpose.

In the manufacture of bags, boxes, and other containers, special equipment has been developed which completes the whole process in a single operation. Similar special equipment has been devised for the manufacture of many other products, although not all of it completes the product in one operation.

Degrees and Stages of Integration

The preceding description of processes and manufacturing procedures does not by any means represent a typical paper and pulp mill. It is, rather, an over-all picture. There are no single mills in the industry which manufacture all kinds of paper and there are but two or three pulp mills which produce all four of the principal kinds of wood pulp.

Actually, the industry is broken by horizontal and vertical lines of integration. The instances of identical degrees of integration are rare. Many of the economic complexities hark back to this hodgepodge within which advantages are constantly shifting and the degree of integration itself is never quite stable.

Pulpwood procurement. Variations in integration begin with the first step, in the procurement of pulpwood. Some mills produce all of their pulpwood requirements under their own auspices from forest lands owned or controlled by themselves. Others produce their wood under similar conditions of ownership through contractors. Still others produce wood that is purchased on the stump from independent forest owners, either by themselves or through contractors. Many purchase their wood from independent owners in prepared form, delivered at the mill or at convenient shipping points. Pacific Coast mills, and a few in other regions, have integrated pulpwood production with lumber manufacture, using for pulp the logs of the species which are more valuable for that purpose than for lumber. In addition, some mills, particularly in the West, use waste from lumber manufacture in their pulp mills.

The effort in each case is to set up methods which will assure supplies at competitive costs consistent with the local conditions of operation and supply. Even though each mill attempts to obtain its woods at competitive costs—naturally the competition is at the source and not at the mill, which may be far or near—the variations in f.o.b. mill costs are wide, particularly in the older regions, because of differences in hauling distance. Although part of such differences may be offset by similar variations in freight charges on finished products, substantially large spreads remain, which may dictate policy with respect to integration and to type and grade of manufacture.

Wood pulp and paper manufacture. The conditions described with respect to pulpwood are primarily important because of their influence upon wood pulp production and costs. In addition to these influences.

of course, there are numerous others which relate to manufacturing efficiencies and techniques. These are important. But the most serious problems arise not so much between individual domestic producers of wood pulp but between domestic producers and users as a group and users of imported wood pulp. This involves the integration of pulp and paper manufacture.

The American paper and pulp industry comprises 535 companies operating 731 mills. Of these there are 120 paper companies with which 188 wood pulp mills are integrated. Only 16 pulp companies are independent—that is, not integrated with paper production under the same management. Contrasted with this, there are 611 paper mills which produce no wood pulp. These mills and some wood pulp producing paper mills which supplement their own production by purchases of different varieties normally consume about 2,350,000 tons of wood pulp annually, which represents about one-quarter of all wood pulp used in the United States. Of this amount, sales of domestic wood pulp for paper amount to about 750,000 tons per year, based upon the record of prewar years. The balance of the consuming mills' requirements is normally drawn from imports.

All important paper-grade groups are produced in both integrated and non-integrated mills with the principal exceptions of newsprint and kraft paper and board. The exceptions are produced under mass production conditions in which a continuous flow is maintained from the wood pile to the finished product, although even here a few newsprint mills purchase their chemical pulp requirements. In other grades almost every possible degree of integration, or lack of it, is represented. Generally, however, the tonnage items in each grade group are produced in integrated mills.

The converting paper mill. The so-called non-integrated mill, generally known as a converting mill, is dependent upon purchased wood pulp. This does not mean that the converting mill is wholly non-integrated, for it invariably produces its requirements of pulps other than wood pulp to the extent to which it uses such pulps. It reduces to pulp its waste paper, and it manufactures its own rag, straw, rope, and jute pulp stock from materials which it purchases. All such pulps, except rag pulp when used exclusively, and straw pulp, are generally mixed with varying percentages of wood pulp, dependent upon the type of paper for which they are used.

Essentially, the converting mill is one which can utilize a variety of pulp materials to produce papers of numerous kinds or of special characteristics. Most, although by no means all, are small and many are old, some being originally pulp-producing mills which were forced to discontinue pulp manufacture. This definition excludes paperboard mills, which use up to 90 per cent waste-paper stock and relatively small percentages of virgin wood pulp. Many such mills are fundamentally designed for mass production of a single grade or a small group of grades. Because of their size, mills in some other classifications approach mass production also.

The self-contained paper mill. The self-contained or so-called integrated mill is essentially a mass production unit, which converts from relatively few kinds of wood pulp, produced in its own pulp mill, a few kinds of paper in large quantities. In such mills pulp is handled in slush form, processes are continuous, and orders are selected to permit long periods of operation without interruption. Whether a self-contained unit is a mass producer or not depends, however, upon a number of factors, among which the size and speed of machines, kind and quantity of its wood pulp, and the economic conditions under which the mill is operated are important.

Most modern self-contained units are designed for mass production. Their capacities are large and their integration is fairly complete. Most mills which were "modern" in 1900 or in 1920 approached mass production at the time of construction, but few of them can be considered in that class now. Many such mills have shifted their production through many grade changes in search of a combination of grades which will yield a higher realization. The shifts were away from the competition of the newer mills in their classification. They became specialty mills or they may have discontinued pulp manufacture, becoming converting mills; they almost invariably use wood pulps of different kinds from what they produce. They tend to approach by different routes the character of the production of the converting mill which uses wood pulp exclusively.

The combined paper mill and converting plant. Integration extends beyond the coordination of pulp and paper manufacture to the paper mill, which converts its paper into paper products such as towels, boxes, and cups in competition with independent converters. Such operations are usually spoken of as combined operations.

In such an operation the paper mill may be a self-contained or a converting type. Its product-manufacturing department, usually adjacent to or a part of the paper mill itself, receives paper from the mill and converts it into any one or group of the thousands of products manufactured from paper.

This integration of primary and secondary manufacture possesses various advantages, provided markets can be serviced quickly and efficiently. Thus most combined operations are close to large consuming markets. But on the other hand, paper products such as paper bags, which can be shipped nearly as easily and cheaply as the paper from which they are made, are frequent combinations in mills far removed from the larger markets.

The typical conversion plant is small, and its distribution is restricted to the local market. There are, however, many relatively large plants which sell certain products, if not all, over wide areas. Such products would naturally be those that can be conveniently and cheaply shipped. Products like boxes, cans, and containers, which are bulky and not adapted to long-distance shipping, are distributed locally.

The urge for the paper mill to enter the conversion field is primarily to stabilize machine operation and to assure permanent outlets. Moreover, if the mill is properly located, it can avoid much of the cost of

shipping and handling paper which the independent must pay. Frequently, the paper mill attempts to stabilize enough of its production through conversion to assure a backlog of machine hours. Then the balance of its production can be varied to meet the vagaries of the market. Theoretically, at least, such a combination permits a mill to escape the full effect of short-running schedules.

Characteristics of Production

Integration and the economic consequences which flow from it are inextricably related to certain unique characteristic uses of productive facilities and to conditions governing such uses.

Some of these characteristics relate to the paper machine itself Others are concerned with investments, rates of turnover, and overhead costs. The nature of expansion waves and their effects upon the stability of the industry are also involved.

Machine shifting. The paper industry is composed of a wide assortment of paper machines of different capacities, ages, and efficiencies. A survey made by the American Paper and Pulp Association in 1935 revealed that 477 Fourdrinier paper machines, representing 23 per cent of the capacity then in operation, were installed prior to 1900 and that 1,137 of a total of 1,394 Fourdrinier machines, representing 65 per cent of the capacity, dated from before 1920. It was brought out in this survey, as indicated in Figure 5, which shows by periods of installation the average widths, speeds, and capacities of these machines, that five machines installed prior to 1860 were still in operation.

These data suggest something more than obstinate persistency on the part of the owners of paper machines. They suggest among other things that in a product of such diverse use and distribution as paper, specialized manufacture as well as mass production has a place. They suggest also that the paper machine is subject to evolutionary processes in the course of which it may be able to maintain for long periods a permanent, if somewhat tenuous, position in the competitive structure of the industry.

These old machines as well as those installed later must compete in the national competition, for none of them manufacture grades which are distributed locally or are controlled by patents or other convention. The original costs of all of the older machines had, of course, been written off, resulting in relatively low overhead costs, an important operating advantage. But their chief advantage lay in the fact that they were able to shift to specialties, to divisions of the market which other mills could not service, and to higher grades, and in doing so to realize a return sufficient to justify continued operation. Because of their shifting, they constituted a floating element in the industry, moving from grade to grade in search of more profitable products.

Most of the machines installed between 1900 and 1920, averaging much larger capacities, were also at some stage in the shifting process Many were considered mass production units at the time of their instal-

lation; many were especially designed for the production of newsprint and wrapping papers. But as competition from modern equipment became more and more intense, they were forced to new grades, usually of higher qualities demanding more specialized processing. Much shifting could not be undertaken until some new processing equipment had been added.

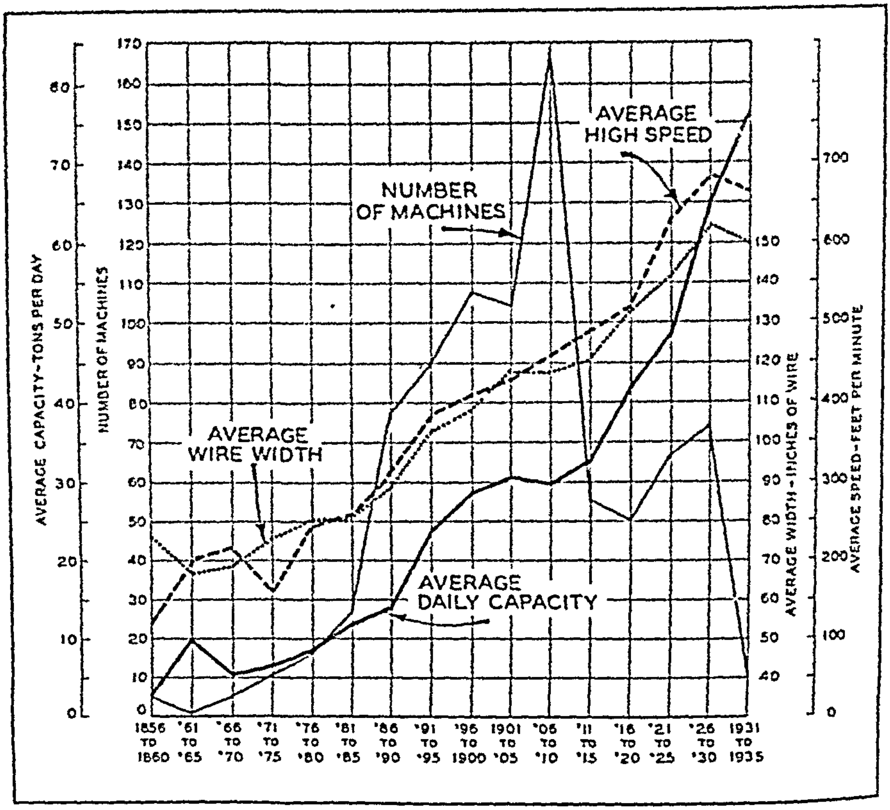


Fig. 5. Average wire width, high speed, capacity, and number of machines installed, by five-year periods, 1860-1935. All machines in operation in 1935. Source: American Paper and Pulp Association Survey.

The classical example of machine shifting is in newsprint manufacture. In 1913 the tariff was removed from newsprint paper and a vast expansion of production facilities began in Canada. There new, modern equipment operating in close proximity to pulpwood supplies and power sources resulted in lower operating costs, which eventually, particularly after 1926, when the expansion exceeded requirements, led to sharp reductions in prices. Then, many American producers, not so well situated. were forced to shift to other grades.

This story is told graphically in Figure 6, which shows what happened to the domestic newsprint industry as a result of Canadian competition. The data cover all mills that were making newsprint in 1910 and those

which subsequently were built in the United States for newsprint production, most of which were located in the Pacific Coast States.

Similar, but less spectacular shifts have taken place in other branches of the industry. In each case the entrance of new sources of supply has forced the weaker mills into a shifting program. The extent to which this exists in the industry is shown in the case of Fourdrinier paper machines in Figure 7, in which the percentage of capacity of paper machines used exclusively for the manufacture of one grade of paper is compared with the percentage which is used for more than one grade. The machines represented by the split capacity are actually in the process of shifting.

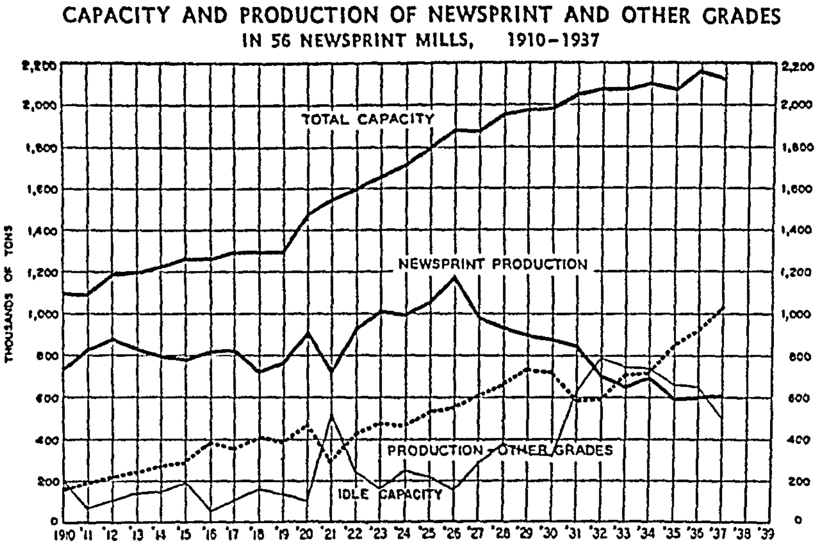


Fig. 6 Shifting in newsprint manufacture: capacity, production of newsprint and of other grades, and idle capacity, 1910-1937. Source: American Paper and Pulp Association Survey.

This more or less peculiar phenomenon had resulted in a characteristic form of growth in the industry. On the paper side, as distinct from paperboard, growth is from the newsprint or the kraft paper base, two products which are particularly adapted to mass production. The expansion in Canada in the 20's and the expansion of the kraft paper industry in the South during the 30's, forced weaker competitors to shift production and by doing so they have helped to meet increased consumption requirements in other grades.

In the past two decades but few new mills have been established to produce grades ranking in quality above newsprint or kraft paper. Of course, during this time many established producers in the higher grades expanded their capacity by machine improvement and by the installation of new machines.

Capital requirements and slow rate of turnover. The construction of a new pulp and paper mill is costly. A modern self-contained unit of

100 tons per day capacity will cost from $2,500,000 to $4,000,000, dependent upon the processes used and the type of production. Larger units cost proportionately more.

The investment per employee and per dollar of sales in the pulp and paper industry ranks among the highest in American industry. In a self-contained unit, investment ranges up to $20,000 per employee, averaging approximately $17,500. In the converting mill, the investment averages approximately $12,000 per employee.

The total value of the primary products produced by the industry as a whole has not in any year equalled the invested capital. The rate of turnover, in the case of self-contained mills, is approximately once in 18 months and in converting mills once in 12 months.

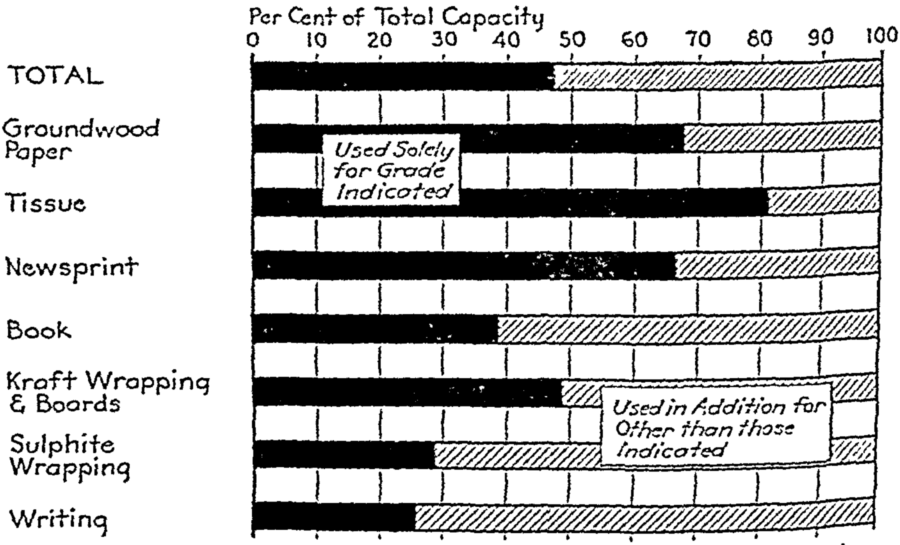


Fig. 7. Fourdrinier paper machines used for the production of one grade and of more than one grade, in percentages of capacity. The machines used for more than one grade are in the process of shifting. Source: American Paper and Pulp Association Survey.

The significance of these data lies in overhead costs and their effect upon production policies. The overhead costs in the industry are so heavy that they make volume of production a prime necessity; they force price concessions for the sake of volume whenever volume falls below an exceptionally high normal production ratio.

There is a significant difference in overhead costs between the self-contained and the converting sections of the industry. This is reflected in different production and price policies. Generally, the converting mill is more interested in sales to retailers, for instance, than it is in long-time contracts with consumers and users. The self-contained manufacturer will sacrifice price on at least a part of his production for the greater stability in volume assured through contracts.

High break-even point. Because of the urge in the industry for high production rate and because of the general willingness to make price concessions for volume, the normal break-even point is high and the margin of profit averages is lower than in most other industries. This fact is illustrated in Figure 8, which shows, for the period from 1927 to 1939, the operating profit on an index basis of a selected group of mills whose capital investment exceeded $400,000,000 in comparison with the average price of paper, on the one hand, and with the capacity and production volume of the industry on the other.

The sharp decline in prices as sales volume dropped during the depression and the hesitancy to raise prices as volume picked up slowly

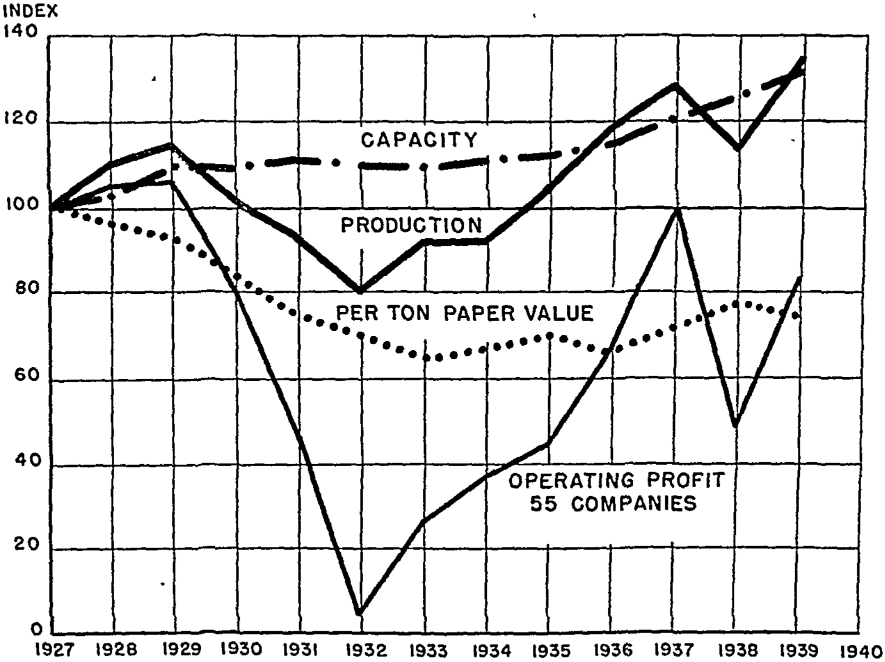


Fig 8 Operating profits of 55 companies compared with capacity and production of the whole industry and average value of paper produced, 1927-1939 Sources: Department of Commerce and American Paper and Pulp Association.

following the depression are reflected in the operating profit trend. These data indicate, particularly in the records from 1936 to 1939, the importance of volume from the point of view of profit. Yet volume standing at 134 over a 1927 basis did not offset fully the contraction in price amounting to 25 per cent as compared with that of 1927. In view of the relatively low operating profits in the industry, this fact indicates that price concessions to attract volume have been carried too far. There is also more than a suggestion that the addition of mass production units in recent years has produced an inflexibility which has had much to do with the high break-even point.

Expansion waves. The conditions just described have had the effect of stimulating paper consumption through price decreases. As prices have moved downward, paper has become a more acceptable substitute for other materials in many products. Coincidentally, manufacturers have been forced to develop new uses which have accounted for important increases in consumption.

At the same time, these processes have reduced the normal margin of reserve capacity to a point where paper consumption, when stimulated by improvement in general business and by speculative purchases, approaches and sometimes exceeds productive capacity. When production volume exceeds 85 per cent of capacity, prices invariably begin to move upward. If the period of high consumption is prolonged, profits accrue rapidly and capital begins to flow into the industry. Under such circumstances, expansion waves are created.

These waves occur in the mass production grades, for during such periods producers of other grades shift to higher types of manufacture for the sake of the better profits and in hopes that they can make the shifts permanent. There is, during such periods, an actual reduction in capacities in the mass production grades.

In spite of such reductions, the addition of one modern unit, or at most two, would usually suffice. Expansion is not so closely curbed, however, for each major producer feels that it is vital to his future program to maintain his relative productive position in his branch of the industry. Under such circumstances expansion soon becomes over-extension—so much so that the normal increases in consumption for many years ahead are taken care of.

The inevitable results, invariably stimulated by a subsequent downward movement in general business, are sharp declines in prices, restriction of consumers' inventories and the accumulation of idle capacity. Such cycles have occurred time and time again in the industry, most recently as a result of expansion in Canadian newsprint, in southern kraft paper and board, and to a lesser degree in pulp in the western states. In every case the effect is transmitted to all grades in the industry, chiefly by machine shifting.

The possibilities of over-all expansion in pulp and paper manufacture in the United States, however, are practically unlimited. There is adequate pulpwood for all types of manufacture except mechanical and sulphite pulps in the older producing regions. There are no patent controls or other convention which would limit expansion. The only limiting element is the flow of capital, and this when it starts is apt to become a flood.

The Influence of International Trade Conditions

It has been pointed out that the United States normally depends to a large degree upon the importation of pulpwood, wood pulp and newsprint paper, all of which enter the United States duty free. These dependencies began because of the lack in the United States of ample supplies of

spruce pulpwood suitable for the production of newsprint paper and sulphite pulp. They were amplified later by the importation of sulphate pulp, principally from Sweden and Finland, to meet the growing demands of consuming mills.

The over-all dependency upon outside sources is illustrated in Figure 9, in which the importations of pulpwood, wood pulp, and paper, principally newsprint, all expressed in terms of the pulpwood required in their manufacture, are compared with the apparent consumption of all paper in the United States, also expressed in terms of the pulpwood required in its manufacture. It is apparent that the period of the most rapid growth of dependency occurred during the 1920's. After southern

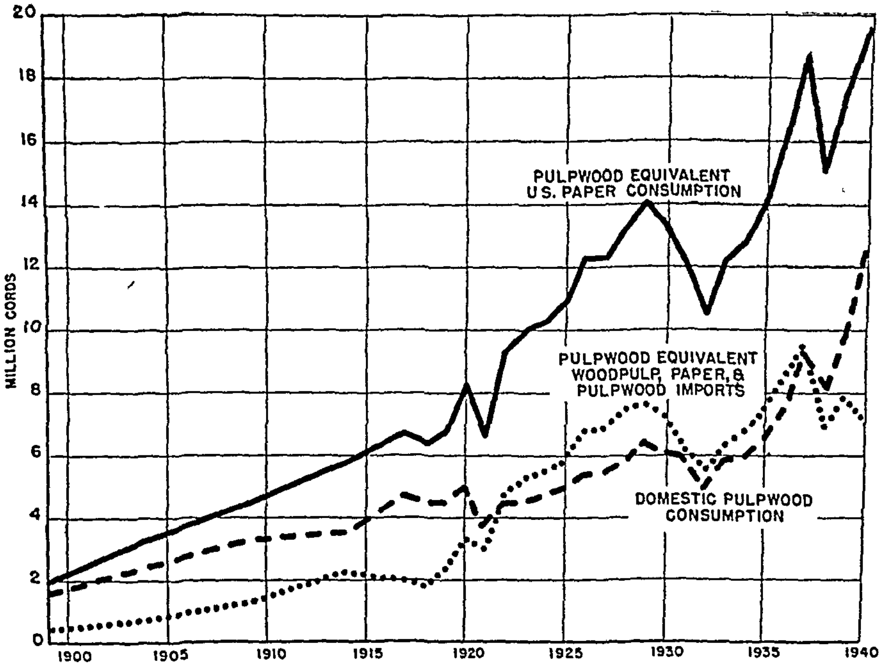


Fig. 9 Domestic pulpwood consumption, domestic consumption of all paper, and imports of wood pulp, paper, and pulpwood, all expressed in terms of the pulpwood required in their manufacture, 1899-1940. Computed from Department of Commerce data.

and western production had reached its present commanding position, and prior to the Second World War, the balance had shifted to domestic sources of supply. The quantity of imports, however, remained high.

Imports, particularly of wood pulp from overseas, are subject to conditions which frequently do not otherwise affect domestic manufacture, and which affect Canadian manufacture only to a slight degree. Overseas imports of wood pulp have in the past decade been affected by depreciation of currencies, by cartel programs and now by the Second World War. In each instance, violent repercussions occurred in the domestic industry. With the exception of a short period in 1937 when a world shortage of wood pulp threatened, and since the invasion of Norway,

which actually precipitated a world shortage, the repercussions have been in the nature of low prices.

For long periods imported wood pulp has sold in the United States below the cost of domestic production. The direct result is unprofitable operation of domestic facilities, which, of course, discourages expansion.

The recent prolonged periods of low wood pulp prices also seriously disturbed balances in paper manufacture, for the converting mills were able to purchase wood pulp at prices which were substantially below the

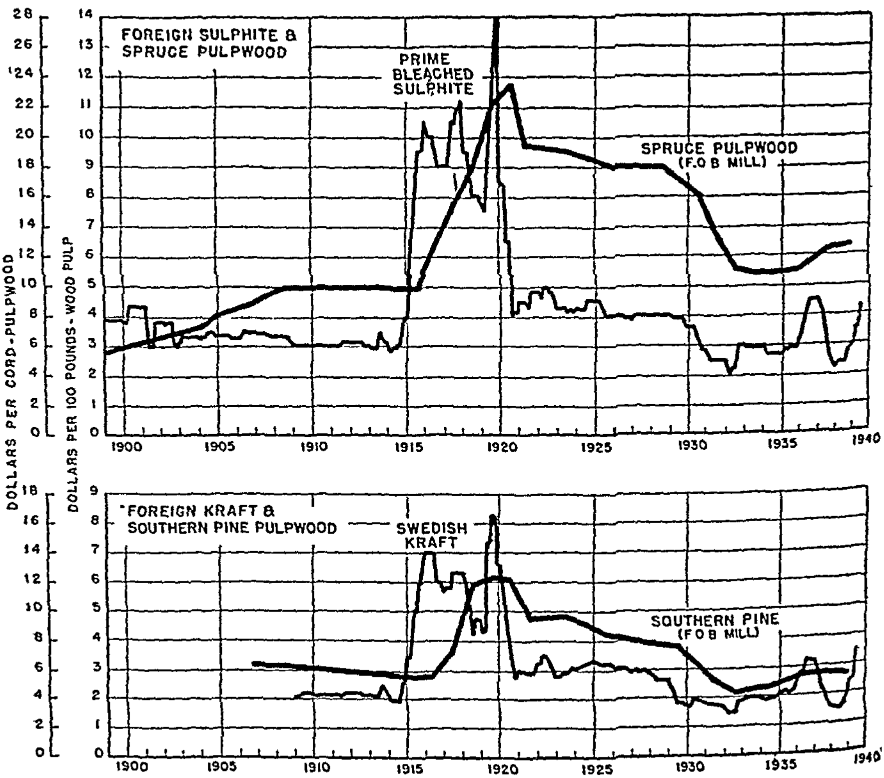


Fig. 10. Price trends of foreign bleached sulphite and Swedish kraft wood pulp delivered Atlantic ports and spruce and southern pine pulpwood f.o b. domestic mills Sources: Pulpwood prices, Department of Commerce; Wood pulp prices, Daily Mill Stock Reporter.

manufacturing costs of their self-contained competitors. In 1937 and at the present time the advantage has swung in the opposite direction.

The disturbance of balances occasioned by the impact of foreign trade conditions is illustrated in Figure 10, in which the average prices of foreign sulphite and sulphate pulps delivered in the United States are compared with the average f.o.b. mill price of the principal kinds of pulpwood used in producing the same pulps in the United States. Pulpwood constitutes the largest item in the cost of pulp manufacture; the price

trends are used in this instance as an index of over-all costs of pulp manufacture in the absence of more complete data.

The difference in the movements of these trends is striking. Pulp prices, subject as they are to conditions of international trade, tend to fluctuate violently and without particular regard to the cost of domestic manufacture as represented by pulpwood costs. The latter, on the other hand, follow slow-moving cycles which have made only one complete turn since the beginning of pulpwood use in the early 80's. Under such circumstances advantages are bound to shift, and in doing so contribute adversely to price movements in either direction.

Consumption of Pulp and Paper

Consumption of pulp and paper constitutes a remarkable record. From the first census to the present, with the exception of depression periods, it has increased steadily. Since the depression of the 30's, paper consumption has broken existing records four times.

Wood pulp consumption. The consumption of wood pulp is chiefly contingent upon the consumption of paper, and when increases occur in the latter, they are reflected in the use of wood pulp.

The over-all trends of pulp consumption and of supplies for consumption are shown in Figure 11, in comparison with the trend of paper production. It is apparent that the major part of the pulp consumed in the United States is domestically produced, but most of it is manufactured by paper producers, who convert it into paper in the same or an associated paper mill.

The consumption of wood pulp by mills which must depend either wholly or partially upon purchases has increased over the years but not in the same proportion as that consumed by self-contained producers. The reason lies in the fact that the latter section of industry has expanded in recent years, principally in the South, at a much more rapid rate than has the converting mill group.

In normal years approximately 2,500,000 tons of wood pulp are required by purchasing mills. Seventy per cent is normally obtained from foreign sources; the balance is supplied by domestic mills, the majority of which are located upon the Pacific Coast.

It is interesting to note the increasing spread between the trends of wood pulp consumption and of paper production. It is caused by the constantly greater use of secondary materials, mostly waste paper for paperboard manufacture.

An increasing amount of refined chemical pulps, chiefly sulphite wood pulp, is being used in commodities other than paper. Consumption for rayon, plastics, and chemicals is mounting each year. In many uses wood pulp is proving not only superior, but also substantially less expensive. It is a form of consumption which is likely to continue to grow.

Paper consumption. The trends of paper consumption, illustrated in broad grade groups in Figure 12, indicate that the cultural uses, represented by writing and book papers and newsprint, have not in recent

years kept pace with the mechanical papers, those used for physical purposes. It is probable that the cultural papers are being affected by the competition of radio advertising, for much of the paper used in news and periodical publications is based upon advertising. Whether or not shifts

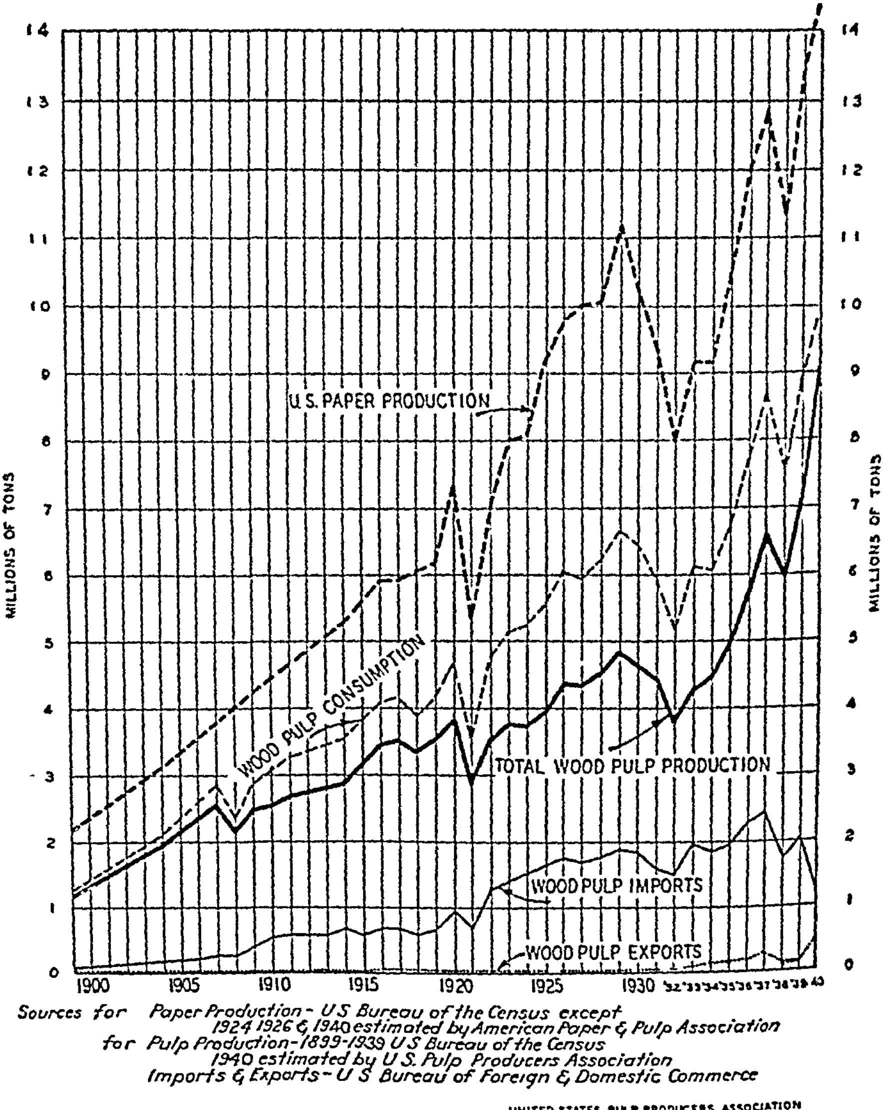


Fig. 11. Total wood pulp production, consumption, imports, and exports, and total paper production, 1899-1940.

back to printed advertising will occur in the future is questionable. Many consider that the use of printing papers is approaching a saturation point. Writing paper, however, shows evidence of continued increase in use. Consumption trends correlate closely wth business and

industrial activity, and it is likely that writing paper will continue to follow these trends.

In the mechanical field the rates of increase are striking, particularly in paperboards and wrapping paper which dominate the shipping-container field. The availability of these papers has made possible the packaging of foods, which has contributed substantially to freedom from contamination. They have been adapted to the shipping field where, through modern packaging design, they have proved to be cheaper not only in original cost but also in freight charges on the container itself. Paper, when properly used, has also proved more effective protection than other materials.

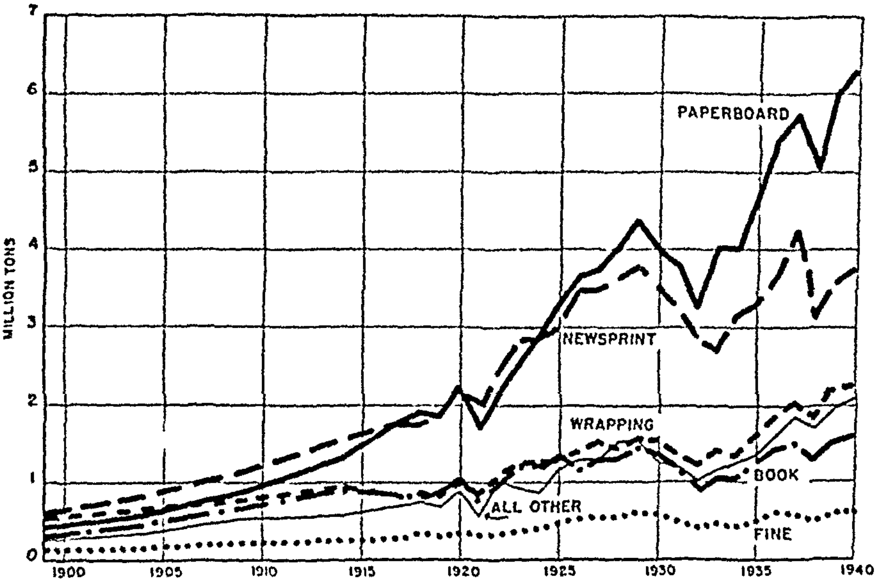


Fig. 12. Paper consumption in the United States by major grades, 1899-1940. Source: Department of Commerce.

Paperboard is making rapid inroads into the field of liquid containers. The paper milk bottle, after overcoming initial marketing prejudices, is being used more and more. As containers for other liquid and wet foods, progress is being made daily.

Among the miscellaneous papers the use of tissue for sanitary and toilet purposes illustrates again the service of paper in sanitary fields. Felts and sheathing and roofing papers, which are dependent upon construction, and particularly building repairs, are being used in greater quantities.

With the exception of newsprint, practically all paper consumed in the United States is domestically manufactured. Exports and imports normally balance in quantity, although in each grade group the specific grades may be entirely different. In general, United States exports are

normally heavy in specialties, and the imports tend to be heavy in the higher grades of the respective grade groups. During war periods, of course, the normal trends of foreign trade are distorted. Because imports of grades except newsprint come mostly from Europe, they are subject to war conditions. These same conditions interfere with other European trade; consequently the world import market turns to the United States. During wars American exports increase many fold. The shifts are not permanent, however, because the United States cannot compete extensively in world markets.

The over-all trends of paper consumption, production, exports, and imports since the beginning of the century are shown in Figure 13. For comparative purposes the capacity of operating mills is also shown.

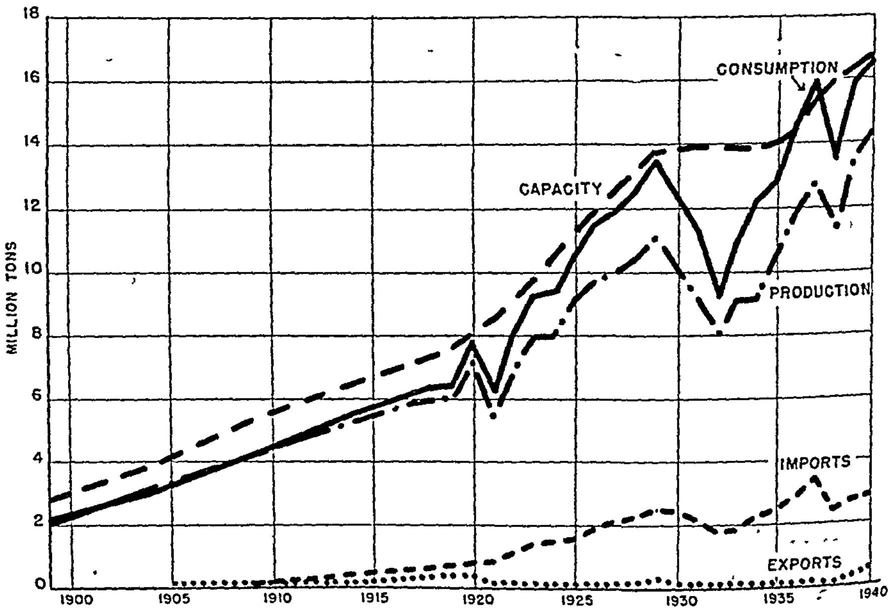


Fig 13. Paper-making capacity and paper consumption, production, imports, and exports, 1899-1940 Source: Department of Commerce.

Paper Prices

One of the chief reasons for the increasing consumption of paper lies in the fact that year after year the real price of paper has been moving downward. This downward movement is due fundamentally to economies in production and distribution in spite of increasing wage rates The economies are caused not only by natural improvements resulting from research and the development of technical control, but also by the conditions of competition described previously, which have forced concentration upon cost reduction.

The trend of paper prices in recent years as shown by the Bureau of the Census for major grades, is given in Figure 14. The downward move-

ments are plainly evident. They are related to the peculiar conditions of the industry and of operations discussed earlier.

Price comparisons by specific grades are hardly possible because of frequent changes in specifications, particularly in the improvements of qualities, and because of shifts from higher to lower qualities on the part of consumers as the specifications of the lower-quality papers are improved. The price trends shown in Figure 14 are in effect weighted averages for broad uses of paper. As such, they take into account shifts of volume from high to lower qualities within the grade group.

Effect of the Second World War upon the Industry

The paper and pulp industry was among the first major American industries to be directly affected by the Second World War. The first ef-

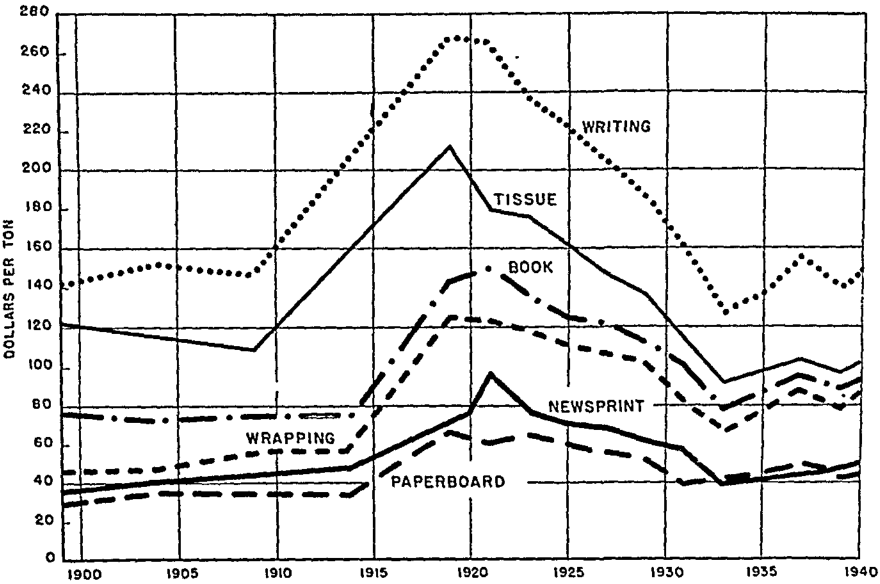


Fig. 14. Trend of average values per ton of major paper grade groups, 1899-1940. Computed from reported production and value of production of all manufacturers covered by the census.

fect was in increased cost of delivery of overseas pulp. Later, when Norway was invaded, the industry was unbalanced by the complete stoppage of overseas imports. Most contracts for overseas pulp which were in effect at the beginning of the War provided that any increased costs of manufacture or delivery caused by war would be paid by the purchaser. Submarine warfare was part of the initial action and neutral as well as belligerent shipping was sunk in increasing tonnages. First insurance rates increased, then cargo rates began to mount, and, in all, the additional shipping charges just prior to the invasion of Norway had increased at least fourfold.

The price of wood pulp in the American market when war was declared was relatively low. Domestic manufacturers increased their prices at the beginning of 1940 and again for the third quarter of 1940. The increases were substantial. In conference with the Price Stabilization Division of the National Defense Advisory Commission, it was concluded that the prices existing in July 1940 were necessary to stimulate production which would offset the loss of imports from overseas, although high for efficient producers operating at full capacity. No further changes in contract prices have been made since that time (July 1941). Meanwhile, production both in the domestic industry and in Canada, and particularly for sale to pulp-purchasing mills, has increased to a point which over-all nearly compensates for the loss of overseas imports.

The national defense program, which involves the shipment of much material that would normally be packed in paper and paperboard, has thrown heavy demands upon the industry. The impact of this program upon all business has increased civilian requirements for paper. In 1941, it is estimated that the national requirements for paper will exceed the record-breaking level of 1940 by at least 2,000,000 tons. To supply these requirements and the export trade, which has increased threefold, will tax the ability of the industry, handicapped as it is by the absence of overseas pulp supplies.

Conclusion

The paper and pulp industry is destined to remain a ranking major industry in the United States. It will continue to depend, as it has in the past, upon domestic consumption. Under normal circumstances it cannot hope to compete in world markets. It is probable that the use of cultural paper will not change substantially in per capita consumption, but the use of paper for other purposes is bound to expand as new uses are developed and substitution increases.

The use of pulp in products other than paper is undoubtedly in its initial stages of development. It is probable that as improvements are made and specifications are standardized, this use will increase substantially.

As an employer of labor and of capital there seems to be no obstacle to further development. In the future, as in the past, the greater demand for paper, which will require an ever-increasing production, will call for a larger number of man-hours of labor in spite of improved efficiencies. Gradually, also, as efficiencies increase, many of the older mills must be replaced. These replacements will necessitate substantial new capital investments.

7

The Book Publishing Industry

Early History of Publishing in the United States

Early days (1638–1801). Publishing in America is nearly 300 years old. The first book issued here was really a pamphlet, *Pierce's Almanac*, which came from the press established by Stephen Day at Harvard College in 1638 or 1639. In 1640 *The Whole Booke of Psalmes* was published. For the remainder of the century, Cambridge continued to supply the colonists with laws, sermons, and almanacs. Other presses were founded from 1660 on.

William Bradford published his first book in Philadelphia in 1686. He later removed to Manhattan, where he was the sole printer for a number of years. Benjamin Franklin, after an adventurous beginning in Boston, established his print shop in Philadelphia in 1728. The great political debates which swept the colonies in the third quarter of the eighteenth century gave a new impulse to reading, and the heyday of pamphlet publishing was brought about by the controversial spirit of the years just before the Revolution.

In the early days, booksellers were usually printers and publishers also, but their major stock consisted of books from England. By 1724, Boston dealers were sufficiently trade-conscious to make their first venture in coöperative action, by holding a convention to boost prices. Pirated editions of English books were common here, but it was difficult at first for colonial printers to meet the prices of imported books.

A Philadelphian, Matthew Carey, founded the American Company of Booksellers in 1801, with members in the 3 printing centers, New York Philadelphia, and Boston.

Early authors. In 1820, about 70 per cent of all the books published for American readers were of foreign origin, but the proportion gradually declined until, by the middle of the century, 80 per cent were by American authors. English writers have been popular in America down through the centuries, however, and the enthusiasm of book buyers here has brought many a British author a fortune. But this stream of riches did not begin to cross the Atlantic until 1891, when our first copyright law was passed, protecting the foreign author. Before that time, some

of the more scrupulous American publishers paid royalties on English books, but many of them had no conscience in the matter. The period following the Civil War was particularly notable for pirating.

In reviewing Seybert's *Annals of the United States*, Sydney Smith coined a phrase whose echo has only recently died down completely: "In the four quarters of the globe, who reads an American book?" Many of our early books were dull legal, medical, or religious treatises, but later came the golden age of American literature, when Hawthorne, Irving, Poe, Emerson, Holmes, and other great names were honored abroad as well as at home.

Early methods of distribution. The itinerant book agent early became a competitor of the city bookseller. Lonely farm and village readers thus had a chance to purchase the *Bible* or *Pilgrim's Progress*, or Parson Weems' famous *Life of George Washington*, and later to buy subscription sets for the parlor bookcase.

Important early publishing houses. New York gradually became the publishing center, though Boston and Philadelphia have never relinquished their literary traditions and are still the homes of important publishing firms.

It is interesting to note the dates when a number of houses still publishing books today were founded: Methodist Book Concern, 1789; J. B. Lippincott Company, 1792; John Wiley & Sons, Inc., 1807; Harper & Brothers, 1817; D. Appleton-Century Company, Inc., 1825; Baker & Taylor (now jobbers), 1830; G. P. Putnam's Sons, 1836; Little, Brown & Company, 1837 (with bookstore beginnings in 1784); Dodd, Mead & Company, Inc., 1837; Charles Scribner's Sons (founded as Baker & Scribner), 1846; D. Van Nostrand Company, Inc., 1849; Houghton Mifflin Company, 1849; E. P. Dutton & Company, Inc., 1852.

• There were some enormous sales in the period before the Civil War. From a series of articles in the *Boston Post* in 1860, we learn that McGuffey's series of school readers, begun in 1836, sold between 80,000,000 and 90,000,000 copies; Webster's spelling books, 30,000,000; Washington Irving's many volumes, 800,000; *Uncle Tom's Cabin*, 310,000. But trade practices were not clearly defined, and a general opportunism made the book business unprofitable on the whole.

Early attempts to establish trade reform. Numerous attempts at trade reform were made. The New York Publishers' Association functioned from 1855 to 1861. The practice of selling books below list price was followed to a disastrous degree during this period. The Booksellers Protective Association, of Cincinnati, formed in 1873, became the American Book Trade Union, and both publisher and bookseller members rallied round the slogan "Underselling is the crying evil of the book trade." Public opinion, however, was against price agreements Some iconoclasts continued to cut prices, and the Union ended 3 years later.

The first trade organ, *American Publishers' Circular and Literary Gazette*, was established in 1856 and was succeeded in 1872 by *The Publishers' Weekly*.

Semiannual auction sales increased the public's appetite for book bar-

gains during these years, and destroyed confidence in original list prices. These sales were held regularly up to 1890. The competition of the subscription-set agent increased, and a flood of cheap foreign reprints lessened sales of American books.

In 1900, the American Publishers' Association was organized. Its members agreed not to sell to retailers who sold books below the net price, but this effort to control the price situation ended in a suit won by a New York department store, with heavy fines meted out to the group of publishers involved for conspiring in restraint of trade. The Association was dissolved, and when the National Association of Book Publishers was founded in 1920, it included in its constitution the determination "to make no attempt to fix or maintain prices."

The American Booksellers' Association was formed in 1901. Among its chief aims have been the maintenance of list prices, bookselling education, and improvement of trade practices. The Authors' League was organized in 1912 and has assumed a powerful position in the industry.

The National Association of Book Publishers was superseded on January 1, 1938, by the Book Publishers' Bureau. The scope of the work of this Bureau has been restricted to certain definite specified services to book publishers, the major function still being the compilation of credit and financial reports on booksellers for the information and guidance of its members. This Bureau is the only official organization of the "trade book" publishers.

Publishing Today

Publishing has numerous ramifications and covers enterprises of varied purposes and magnitude. Publishing houses numbering 247 and issuing 5 or more books during 1939 were listed in *The Publishers' Weekly*, January 20, 1940, with a total output of 7,993 new books and new editions for the year (other publications brought the grand total for the year to 10,640 titles). Among these were large firms with lists of from 200 to 600 titles issued in a year; smaller, more specialized houses whose output covered from 50 to 100 new books; university presses; publishers of textbooks, or medical or law books, or technical books exclusively; firms issuing children's books only; regional publishers producing literature about a special section of the country; publishers of subscription sets; fine presses dedicated to beautiful editions for the libraries of collectors.

All these clases of publishers have developed special techniques for securing and marketing their product, but if we describe the business of the so-called general publisher issuing fiction and nonfiction for sale through the retail bookstores, we shall touch upon the major points of interest to that nebulous person, the "average reader."

Choosing the books. The selection of manuscripts is the first step in the long process of connecting writer and reader. Amateur authors pour an apparently inexhaustible stream of manuscripts into publishers' editorial sanctums. And, contrary to disgruntled opinion among some writers, every one of these bulky typescripts is considered. A reader

goes through them rapidly and expertly, searching for the rare plum which makes the expense of handling this unsolicited flood of manuscripts worth while. Publishers' estimates vary, but the percentage of acceptances is undoubtedly low; some say 2 per cent, others 10. They continue, however, to give careful attention to these unsought offerings from authors, because of the gambling chance that a book with originality and vital appeal may be found among them.

The majority of the publications on the general publisher's list are the result of solicitation, and reflect the acumen and special flair of the individual house. The publisher's task has been likened to that of the managing editor of a newspaper. There is the same need for constant feeling of the public pulse, for sensing the kaleidoscopic shifting of public interest. But the publisher must have a longer view than the editor. He has to determine this spring whether a book planned for publication a year or a year and a half hence will find the public ready for it. He must foresee changes in taste long before they have crystallized.

Often the publisher has an idea for a book and selects an author to write it for him. Frequently he secures new writers through established authors already on his list. Literary agents, knowing his needs, offer selected manuscripts of a type likely to find a place on his list. He makes a trip to England, or sends a representative abroad to contract with British and continental publishers for the American rights on books which in his judgment will be successful here.

Fashions, current events, scientific discoveries, changes in education —all affect publishing directly. Books of literary distinction still have a central place on many publishers' lists, but a well-rounded and therefore profitable list must contain books of varied content to keep up with the veering winds of public interest—a certain number of novels, a group of biographies, books of historical, scientific, or economic interests, a little poetry. Most houses keep a fairly regular proportion among the different classes, so that each season's list will be well balanced.

Several readings are usually given a book before it is finally accepted. If it is on a special subject, the judgment of an outside expert is often sought. The traditions of the individual house, as well as current book-buying demand, affect the manuscript's fate.

There are a multitude of stories in the industry of one firm or several firms rejecting a book which later, on another publisher's list, climbed into the best-selling ranks. The publisher faces higher hazards than almost any other businessman; but his intangible rewards, when he makes a real discovery, are extremely gratifying, and monetary returns frequently follow.

Making the Books

Number of copies. After the contract with the author is signed, a most intricate problem faces the publisher: the decision on the number of copies to be printed. If a large quantity may safely be issued, the manufacturing cost naturally is reduced considerably, but there is the

difficult task of predicting just how many copies the public will absorb. Since he works on a narrow margin, the publisher does not dare to print too many copies and have them left in his warehouse. If the book is by an author of established reputation, sales of his previous books, and the advance orders secured from booksellers for the new title, help him to decide on the quantity for the first printing; but if the book is by a new author or on a subject just emerging into the limelight, there is more uncertainty and the initial printing order must be conservative, despite the temptation to shave costs by printing a larger number.

Determining price. The determination of the list price of the book is another important factor. The customary prices for novels are now \$2 and \$2.50, and for nonfiction \$3, \$3.50, \$3.75, \$4, or \$5, with higher prices for books of exceptional length or with costly illustrations. There is a "right price" for a book, one at which it appears to bookseller and customer to be a fair value, and the publisher suffers if he charges more than "the traffic will bear." Still he must meet his costs.

Figures vary from publisher to publisher and period to period, but the figures in Table I give a rough idea of production and distribution costs

Design and make-up. The design of the format of the book is entrusted to the manufacturing department of the publishing house, and negotiations with paper manufacturers, printers, engravers, cloth-makers, and binders are handled by this department.

A layman, picking up a volume from a bookshop table, rarely visualizes the amount of art and thought and precision in the making which the book represents. If its typography and general proportions are pleasing, the designer who received the manuscript from the editorial department must have planned it, not only with the centuries-old traditions of good bookmaking in mind, but with a feeling for what was fitting and appropriate for this particular book, giving it a form that would subtly convey the quality of the book itself. Many books are workaday production jobs handled in routine style, but more and more publishers are recognizing the importance of better make-up and design. The American Institute of Graphic Arts, through its annual selections of the "Fifty Best Books," and traveling exhibits, has done much to improve typographic standards in recent years.

The problem of size. Novels are usually 12mo size, approximately 5¼ inches by 7¾ inches; nonfiction, biographies, books of travel, and so forth, 8vo, 6 inches by 9 inches. There is an unfortunate tendency on the part of the average book buyer to think he is cheated if he does not get a bulky book, although the less bulky papers give a better printing surface and have greater durability. As the public in recent years has become more conscious of beauty in the format of books, publishers have tended to make thinner books. This is in line, too, with the need for economy in shelf space in modern city apartments.

Selection of paper and cuts. The kind of paper used in a book depends largely upon its contents and length. If the book contains no line cuts or half tones, and is not excessively long, an antique or kid-finish paper is suitable. If line drawings appear, a machine-finish or English-finish paper gives better results, because it is smoother. Half tones may also be printed on English-finish paper, although they show up much more clearly on a supercalendered or coated stock. A hard, smooth-surfaced paper is of course desirable when a large number of pages makes it necessary to keep bulk at a minimum. The offset process is successfully used in color printing in books today and, most notably in the children's book field, has produced some excellent volumes, with a great deal of softness and rich tonal values.

Determining type and layout. The selection of the type face to be used in the text, the size of the type, the type area of the page, and the designing of a harmonious title page must be made simultaneously with decisions as to illustrations, if any (many modern books are unillustrated). The designer's ingenuity in handling specifications for the layout of the preliminary pages in the book, title, table of contents, preface, and so forth, and for the headings throughout the text, may enhance or mar the beauty of the book.

Printing and binding. The type is set by machine, and proofs are run off in long galleys for the author's corrections. If the book is likely

to be reprinted, a set of electrotype plates is made for the final printing. The book is made up in forms of 16, 32, or 64 pages each, and the sheets are folded into "signatures," ready for binding.

Various attempts to market paper-bound books in the United States have not been unusually successful. Since with our modern machinery cloth costs but a few cents more than paper, cloth binding is almost universally used, and the designer again has a chance here to use taste in the selection of color and texture. Now and then colored "boards" are used, with a cloth back strip.

Copyrighting the book. An essential feature of a book is the copyright notice, which must be printed either on the title page or the page following, with the word *Copyright*, followed by the year of publication and the name of publisher or author, whichever one owns the copyright. The law requires that 2 copies be sent to the Register of Copyrights in the Library of Congress, with a formal application blank and a fee of $2 The term now runs for 28 years from the date of first publication and may be renewed for another 28 years. A bill for revision of the copyright law to amend and consolidate the acts respecting copyright is now in committee of both the House of Representatives and the Senate.

Distribution

Formerly publishing was concentrated chiefly in the fall season, but there is now a more even spread through the year, and many important books are issued in the spring.

The planning of the paper jacket has assumed great importance in the launching of a new book. It serves as bait and must be provocative, so that it will catch the wandering eye of the book-browser, and induce him to pick up the book, read the descriptive "blurb," and perchance buy. Bookshop windows, proverbially drab in tone, have gained new color and selling appeal with the improvement in jackets in recent years.

Often the paper cover is ready before the printed book, and goes out with the "dummy" copies the publisher's salesman carries to show to booksellers, as an aid in getting advance orders. The larger city bookstores are visited several times a year, and in the intervals are reached by carefully built-up mail promotion and advertisements in the trade magazines.

The smaller cities are covered by travelers once or twice a year. The large jobbers with thousands of small accounts in gift shops, drugstores, stationery stores, and so forth, offer the publisher a valuable additional market. The larger rental library chains, which absorb a great deal of fiction, offer another valuable market.

Available market. Estimates of the number of bookstores in the United States vary with the definition of a bookstore. There are about 5,873[1] shops dealing chiefly in books (the larger book sections in department stores are included in this figure), and perhaps 900 more stores whose accounts bulk fairly large in the publisher's total annual sales

[1] *American Booktrade Directory* (New York: Bowker, 1939).

volume. Circulating libraries and small book departments in gift and drugstores have grown in number in the last decade, because of the aggressive methods of the large book wholesalers.

Public library orders are another strong factor in the industry. Recent statistics of the total annual expenditures of free public libraries in the United States were $51,594,137. On the basis of 25 per cent of the libraries' expenditures being for books, periodicals, binding, and rebinding, the approximate amount spent for these purposes would be about $13,000,000.[2]

Volume of books produced. The United States Department of Commerce census of book manufacture for the year 1937, the latest available figures, gave a total figure of 197,359,076 books, including 72,771,685 textbooks (which are not sold through the regular trade channels). If we estimate that these books were sold at $1 each, which is below the average price, the total volume for the year, exclusive of schoolbooks, would be $124,587,391, or about 1 book per capita. This is low, but America is only gradually becoming a book-reading nation. The universal popularity of magazines, most critics hold, diminishes the reading time for books.

What creates the demand for a book? What sells books remains a great conundrum in publishing and bookselling circles. Publishers spend 10 per cent (often more) of the list price of the book for advertising, a larger allotment than most other industries make, and yet publicity does not inevitably make a book sell. Nor do enthusiastic reviews make it sell, though they undoubtedly help. The trade has come to believe that "word-of-mouth" advertising is the decisive factor. Skillfully planned publicity may help to start this reader-to-reader verbal selling, but there are instances on record which indicate that it is the book itself which gives off the curious spark that starts the conflagration. If the book contains the intangible quality, the "life," which will carry it into the best-selling ranks, the public will discover it for itself. Probably it is this incalculable element in the book business which attracts people to it, and keeps them devoted and interested through the years, though other lines of work might prove more lucrative.

Advertising as a factor in sales. There has been a tendency in recent years to concentrate advertising in a smaller number of media, rather than to spread it thin over a wider range. Each book's advertising appropriation is determined individually and apportioned for announcements in trade magazines, in the book supplements of metropolitan newspapers, and in magazines of national circulation. For books which must reach a special audience, other carefully selected media are used, and are often supplemented by a mail campaign to "key people" who can influence sales. Once a book starts to sell rapidly, an additional appropriation for continued advertising helps to keep the title before the public, and thus to increase sales and profits for retailer and publisher.

The sending out of review copies and news stories about the book and

---

[2] American Library Association.

the author is handled by the publicity director, who must be an ingenious person who can seek out all possible avenues for exploiting the book and arousing interest in it. The value of books as news makes it possible to secure a great deal of free publicity in the press.

There must be close coöperation between the sales department and the advertising department if the book is to reach its maximum sale. Display helps for dealers and promotion letters are often jointly planned by the two departments.

A difficulty in publishing technique, which outsiders frequently fail to appreciate, is the fact that each new title is a new and separate problem in promotion. A special campaign to reach the customers who will want that individual book is required. Unlike the manufacturer of soap or cigarettes, the publisher cannot count on the cumulative effect of the advertising of former seasons to produce sales for this year's product. While certain imprints are recognized and valued by the exceptionally discriminating book buyer, the majority do not notice the publisher's name. Each book is new, unless it is by an author with a large, loyal public, and even then a poor book may not attain the sales won by his previous books.

Growing markets. In the last decade nonfiction books have reached unprecedented sales totals and often vie with novels in popular favor. This growth has coincided with a sizable expansion in national book demand, for which varied explanations are given by critics and publishers The great increase in the number of Americans who go to high school and college undoubtedly has affected the book market. It appears, too, that the automobile, the radio, the airplane, the motion pictures, all of them considered by conservatives to be rivals of books, have, on the contrary, given the public new reasons for reading.

Twentieth-century opportunities for travel and world communication have enlarged the horizons of the average citizen and have made him more interested in the information books offer him. There is still a long distance to go before America has the book-buying public she logically should have, but the growth in the past 20 years has been notable.

The National Association of Book Publishers.[3] The coöperative campaign of year-round book promotion carried on by the National Association of Book Publishers has been a factor in this growing demand for books. It had its beginning in the first Children's Book Week campaign, conducted jointly by booksellers, librarians, publishers, and leaders in the Boy Scout movement in November, 1919. Book Week has been observed annually since then and has become a big event on school and club calendars. Widespread distribution of posters by well-known artists, children's book exhibits, plays and pageants, magazine articles—a great variety of publicity devices have been used to focus attention on the importance of choosing the right books for boys and girls.

Out of this successful coöperative project grew the Association's year-round promotion program. Seasonal window-display material supplied

[3] The National Association of Book Publishers has been superseded by the Book Publishers Bureau (see p 161).

gratis has helped to persuade dealers to make their displays timely. Merchandising suggestions for various classes of books, developed by groups of publishers (religious, business, technical, and so forth) have also been effective in enlarging markets and have assisted retailers to reach new bookbuyers.

The Association has sought to increase book outlets, and has assisted prospective booksellers with concrete advice about capital needed, locations, and similar problems. It also has active contacts with libraries and with national educational and welfare organizations.

Its services to members include constant legislative work directed toward the welfare of the industry, a central information service, and coöperative promotion lists. A Joint Board of Publishers and Booksellers, organized in 1930, has been studying problems of mutual interest and has set up a "standard practice" on several controversial subjects.

Special sales promotion methods. The selling and advertising procedures outlined above are the ones used by the general publisher. Medical books, scientific books, and other special classes are sold chiefly by mail, with few store outlets. The publisher keeps large classified mailing lists of prospective purchasers, and circularizes them whenever a new book appears, usually offering to send the volume on approval Textbooks are sold by personal solicitation by salesmen, who visit schools and colleges and endeavor to secure adoptions for class use. Orders are then placed through local dealers who handle educational books.

Subscription selling has passed through many phases, and the book agent is still an important part of the publishing industry. At a conference with the Federal Trade Commission in 1924, subscription publishers adopted a code of practice which eliminated many of the unfair methods formerly pursued by certain unscrupulous firms. Encyclopedias, reference sets, and sets of standard authors are sold through house-to-house canvassing, coupled with display advertising.

Many of the larger publishing houses have several departments, and issue subscription books, medical or educational books, or other so-called "bread-and-butter" lines, in addition to the more hazardous general lines of fiction and nonfiction. In bad seasons these departments, which have a steadier income, form a most valuable "backlog" for the firm.

Remainders and reprints. When the general publisher finds himself with surplus stock of an unsuccessful book on hand, he usually disposes of it to a dealer in "remainders," receiving a small fraction of the original list price per book. The books are then sold at bargain prices in department stores and drugstores, and through the marked-down tables in the regular bookshops. Some firms believe that this practice tends to cheapen books and lower the prestige of author and publisher, and that it would be better to take complete losses on these books, rather than to sell them at reduced prices. Others maintain that they reach a special bargain-hunting public and that it is better to salvage whatever one can from these unprofitable publishing ventures.

Even a successful book may have only a short term of active sales Because of the great number of titles published and the modern clamor

for what is new, many books cease to sell after two or three months. Others have a much longer lease on life and, with effective continued advertising, keep on turning dollars into bookstore cash registers. Books of special merit are kept in print for years, and form a regular part of the bookseller's stock.

Reprint editions at 75 cents and $1 provide a second market for books which have reached a fairly large sale at the original price. The publisher rents plates to the reprint firm, and is paid a royalty, half of which goes to the author. Larger editions are possible because the demand has been tested by the first edition. The reprint firms, issuing fiction and nonfiction, have developed thousands of new outlets in drugstores, though their books are also extensively sold through the regular bookstores. The development of this enormous business has created many new book buyers, and brought additional profits to all branches of the trade There are interesting stories of surprises in reprint selling. Books which did not sell very widely in the original edition sometimes reach exceptionally high totals as reprints; others reverse the process, selling well at the first price and moving slowly as reprints. Some motion-picture reprint editions have climbed to sales of more than 1,000,000 copies.

A number of publishers issue their own series of reprints, instead of handling them through an outside firm.

Other by-products of publishing are motion-picture and dramatic rights, and "second serial rights," serialization after publication. The publisher's contract with the author determines whether he shares in the income from the sale of these rights.

Publishing—Its Function and Importance

Is the making of books a business or a profession? It has elements of both. Although not a large business as compared with many of our great mass-production industries, publishing has an extraordinarily important function It makes a continuous contribution to civilization since it provides a means for transmitting ideas to the world and for preserving them; it also is constantly adding immeasurably to the sum total of human happiness. It has always attracted men and women of individuality and conviction, often combined with a certain gambling instinct, for it is one of the most difficult of all ways of earning a livelihood, and one of the most fascinating.

8

The Newspaper Industry

The Function of the Newspaper

The word "industry" suggests raw materials, machinery, and a finished product which can be weighed and measured. It is a little unfortunate that this conception should be common, for in any field of endeavor the important facts have to do not with the tangibles but with the intangibles; not so much with the things that satisfy needs as with the factors in human nature that create the need and invent the means of satisfaction. We may say of the automobile industry, that its product is not so much automobiles as it is speed and change. Likewise we may say of the newspaper industry, that its product is not newspapers so much as it is the fulfillment of man's instinctive need to know about his world and his fellows.

The final significance of the modern newspaper does not lie in the amount of its capital or in the size and the speed of its presses. These are important not in themselves but as symbols. They have made it possible to bring the news of the day, in the United States, at least, literally to every man's door, every day in the year. Within the limits set by human nature they permit the creation of an intelligent public opinion such as has never before existed in the world. Without daily newspapers, read by nearly everyone, democracy, even in its present imperfect state, would be impossible in a nation so large and complex as the United States. The newspaper industry is as much a part of democracy as Congress or the New England town meeting. We should read this implication into the statistics of newspaper enterprise.

Printing and the Spread of Knowledge

The art of printing is a development of the art of writing, which every civilized people has sooner or later achieved. It is simply a means of lessening the labor of making copies by hand. It is a means so natural that we cannot say whether the invention of printing made possible the spread of knowledge or whether the desire and need for knowledge necessitated the invention of printing. The Chinese and the Europeans stumbled upon it independently, at periods of time far separated, and

apparently for the same reasons—that people wanted to read and that hand copying was too expensive. The improvements in the art since the days of John Gutenberg, nearly 5 centuries ago, have consisted mainly in the application of mechanical principles to save time and labor. They have kept step with a steady improvement in the position of the masses of mankind, and they seem to have been both a cause and an effect of that improvement.

History of the Mechanical Production of the Modern Newspaper

Three steps may be considered as essential to the physical production of the modern newspaper: faster and cheaper typesetting; lower-priced paper, notably that made from wood pulp; and faster presses. The most notable strides in these directions have been made during the past century and many of them within the past generation. To these elements may be added improvements in communication, including the steam locomotive, the steamship, the airplane, the automobile, and the auto truck; the telegraph, the telephone, the submarine cable, and the wireless telegraph and telephone; and the transmission of photographs by telephone, telegraph, cable, and wireless. Without these aids the newspaper of today could no more serve its public than a transportation company could handle the commuting traffic in and out of New York by means of horse-drawn stagecoaches. We may go far back in history—even as far back as Augustinian Rome—for the origin of the *idea* of the newspaper. We may trace it in posted bulletins, town criers, pamphlets, and news letters. But the conception of printed news as a commodity offered to practically everyone is a thing of yesterday.

Early printing presses. The speed of printing presses did not greatly increase for many generations after the European invention of printing. Gutenberg's first printing press was a modification of a wine press, operating with a lever and screw which required several turns for each impression. Benjamin Franklin, more than 300 years after Gutenberg, used a press which, according to Kenneth E. Olson,[1] "required 9 separate hand operations and was capable of turning out at most 350 'pulls' an hour." In 1814 the London *Times* was getting out an edition of 10,000 copies in about 6 hours with 12 presses worked by 24 men—an average of a little less than 140 copies an hour for each press No wonder newspapers were so expensive that even the well-to-do rented them or organized "newspaper clubs" to buy them. When, in November, 1814, the London *Times* discarded these presses and installed the first newspaper cylinder press, it described the achievement as one "which gave to the world printing by steam on an almost gigantic scale." The new press was built by Fredrich Koenig; it printed on one side of the sheet only, and it turned out 1,100 copies an hour!

First cylinder printing press. The first cylinder presses consisted essentially of a revolving cylinder under which the type, fixed on a flat

[1] *Typography and Mechanics of the Newspaper.* (New York: D. Appleton-Century Company, Inc., 1930.)

bed, was moved back and forth to make the successive impressions. Two thousand impressions an hour, or 4,000 if the press was fed from both ends, were about the limit of speed. Later the type itself was mounted on cylinders, the number of feeders was increased, and with 10 feeders one press could turn out as many as 20,000 impressions an hour. The type could not be printed in more than one-column widths, or it would pull out. Sometimes it pulled out, anyhow.

The stereotype plate. The next step was the stereotype plate, by means of which the page of type, after being set and locked in the form, was used to mold a page-sized paper matrix, or "mat," from which a semicylindrical cast and any number of duplicates could be made, and with sufficient presses and feeders any number of impressions per hour could be turned out. Then came the continuous "web" of paper in place of the separate sheets, with cutting and folding machines reducing the amount of hand labor to a minimum. The high speeds of the present day —running as high as 50,000 32-page newspapers an hour—were in sight.

The linotypes and monotypes. Meanwhile numerous attempts had been made to increase the speed of typesetting, first by machines designed to pick type out of a case and arrange it, then by the modern linotypes and monotypes, by which lines or letters are actually cast in molten metal. The first linotypes, the invention of Ottmar Mergenthaler, were set up in the plant of the New York *Tribune* in 1886. These and similar machines multiplied 7 or 8 times over the speed of expert hand setting. Without them the voluminous newspaper of today would be impossible.

Wood-pulp paper. Wood-pulp paper came into use in the eighties. It, too, is a necessity to the large, low-priced modern newspaper. It is estimated that in 1939 the United States produced 939,442 tons of newsprint, and imported from Canada, the chief source of supply outside this country, 2,205,559 tons.

Printing ink. The fundamentals of ink-making have perhaps changed less than those of any other department of printing. The earliest printers seem to have used linseed oil and lampblack, and these materials or their equivalent are the bases of printing ink today. But inks have kept pace with the development of high-speed printing. Rapid drying has been made possible by adding rosin dissolved in mineral oil, special inks have been produced for the rotogravure presses, on which the lines of the pictures or letters to be printed are engraved in the printing surface instead of being raised above it, and the variety and satisfactoriness of color printing have been increased by the use of inks containing coal tar dyes. The American printing ink industry, though not a large one, is a highly important one. A change in newspaper printing in recent years has made available two-color printing of advertisements in weekday editions. Although the results are crude, the number of newspapers offering such color advertising is increasing.

Journalism

Change in the character of journalism. Whether we think of large circulations as the result of these mechanical improvements in news-

paper-making or of the mechanical improvements as arising from an increased demand for newspapers, the fact remains that high speed and wide distribution have been accompanied by changes in the character of journalism. Let us trace this development very briefly by going back to the beginning of newspapers in America. The first of these was the Boston *News-Letter*, established in 1704. It was not until 8 years later that the Pennsylvania *Packet and General Advertiser*, published in Philadelphia, became the country's first daily. These and other newspapers published in late colonial times and in the early years of the republic dealt largely in political and commercial news received by sailing ship from Europe, carried advertisements, and were highly controversial. They were read in coffee houses and other public places. Only the well-to-do could afford individual subscriptions.

Two theories of journalism. A new kind of journalism, intended for popular consumption, appeared in the fourth decade of the nineteenth century. Two opposing theories were in sharp conflict for more than a generation thereafter. One was reliance upon the sensational handling of news. This kind of journalism in America took its rise from two pioneers—Benjamin H. Day, who founded the New York *Sun* in 1833, and the elder James Gordon Bennett, who established the New York *Herald* in 1835. These were penny papers, and they went in for sensation and scandal in what was for that time a big way. The second theory was represented by Horace Greeley's New York *Tribune*, which was founded in 1841 as a penny paper but later went to two cents. The *Tribune* achieved its earlier fame more because of Greeley's editorials than because of its news services. It was, in short, an "organ"—the prototype of many newspapers with vigorous editorial pages and the first really spectacular display of "personal journalism." The indefatigable news gatherer and the editorial thunderer were to compete for attention for many years to come.

Day and Bennett sensationalized their news on the theory that the "man in the street," whom they were perhaps the first to discover, was an emotional rather than a reasoning creature. Scandal and crime, with a dash of romance, were the baits offered him. It is obvious that even then the sensational papers did not reach as large a fraction of the public as do many even of the conservatively edited papers of today. At the outbreak of the Civil War, nearly a generation after the establishment of the "penny press," Bennett's *Herald* had a circulation of about 75,000 a day, which was said to be the largest in the world; Greeley's *Tribune* had a daily circulation of 55,000, though its weekly edition, mailed throughout the Northern States and used primarily as a political organ, reached about 232,000; the *Times*, established in 1851 by Henry J. Raymond, had reached 40,000 during the first 6 years of its existence but had not passed the *Tribune*; and the *Evening Post*, a conservative newspaper with an influence out of proportion to the number of its readers, had but 18,000. Outside New York City, such papers as the Springfield *Republican*, the Philadelphia *Evening Bulletin*, the Washington *Star*, the Detroit *Free Press*, the Boston *Post*, the Boston *Herald*,

and the Chicago *Tribune* were already flourishing All of them were the products of outstanding individual editors.

Conflict between types of journalism. If we follow the course of journalism through the Civil War, the Spanish War, the First World War, and down to the present day, we can distinguish a continual conflict between conservatism and sensationalism. The Civil War was in itself so vast and so tragic that it was hard to exaggerate. Sensationalism for its own sake was discouraged then and for 2 or 3 decades thereafter. It was revived in its modern form by Joseph Pulitzer in his morning and evening *World* and by William Randolph Hearst in a chain of newspapers stretching from coast to coast. It declined after its peak during the Spanish War, or rather was reduced to a formula which yielded few new ideas or surprises. After the First World War it reappeared in the new form of the tabloid, in comparison with which the older type of sensational newspaper sometimes appeared almost conservative. The tabloid, depending largely on pictures, probably tapped a stratum which found reading uninteresting and thus added many thousands to its circulation. It should be added, of course, that the tabloid form is not in itself evidence of sensationalism and that there are tabloids which are no more sensational than their full-sized contemporaries.

The long war between the "personal journalism" of the newspaper dominated by a single individual and expressing that individual's private convictions on its editorial page and, on the other hand, the journalism which emphasized the news has ended in the victory of the latter type. This does not mean that the editorial page has ceased to be important, though it consists nowadays far more of thoughtful interpretations of the news and far less, in most cases, of bitter controversial material. But the great developments have been in a fuller and more diversified presentation of the news and in more extensive, more scientific, and on the whole far more attractive advertisements

The publisher of today. The successful publisher of today may be and sometimes is also a great editor. But he must be able to do more than direct a vigorous editorial page He must be an organizer able to put life into the news, advertising, circulation, and mechanical departments. He must be a good businessman, a good judge of public taste, and as farsighted and public-spirited in his business policies as in his editorial policies.

Economic Aspects of the Newspaper Industry

The newspaper industry is large because people need to know what is going on, because high-speed manufacturing processes make it possible to tell them what is going on very soon after it begins to go on, and because advertising is a commodity for which sellers of goods and services are willing to pay. The industry is large in the aggregate and it contains a considerable number of large units—both individual newspapers and newspaper chains—as well as many more of small or medium size. It is characterized by great coöperative enterprises and by syndi-

cates which distribute news, feature articles, and pictures to numerous individual newspapers. Our approximately 1,950 daily newspapers employ nearly 275,000 persons, have an annual payroll of $400,000,000, and receive an annual income of more than $850,000,000. The daily newspapers printed in English alone have a total average net paid sale every day of 41,131,000 copies, and their total annual consumption of newsprint paper is 3,500,000 tons. The weekday newspapers have an average circulation of almost 20,000 apiece, our Sunday papers an average of approximately 58,000 apiece. Even though these averages are brought up by a few great newspapers and are thus not truly representative, they do give an idea of the magnitude of newspaper enterprises.

Among independent newspapers of large circulation we find the New York *Daily News* issuing 1,948,759 copies on weekdays and 3,483,616 on Sundays; the Philadelphia *Bulletin*, with a 6-day average of 426,606; *The New York Times*, with a daily average of 477,385 and an average on Sundays of 802,386; the Chicago *Tribune*, with a daily average of 1,078,886 and a Sunday average of 1,132,602; and the Kansas City *Star* and *Times*, afternoon and morning editions of the same paper, with 311,985 and 307,540, respectively. The New York *Herald Tribune* has 356,512 on weekdays and 539,023 on Sundays, and the New York *Sun* has a 6-day average of 312,112. The foregoing figures are averages for the 6 months ended September 30, 1940.

Development of chain newspapers. Chain newspapers have been in existence for more than a generation. The latest listing (1940) shows 60 groups totaling approximately 300 separate newspapers.

"Chain journalism" has been criticized on the ground that it tends to standardize news, editorials, and features, that it destroys local editorial independence, and that it gives the owners of the chains a dangerous power over public opinion. For a defense of the group system we may quote Roy W. Howard, chairman of the board of the Scripps-Howard newspapers, writing in the *North American Review:*

> Chain newspaper operation needs no apology. Newspapers in the long run, almost without exception, succeed or fail according to their ability to serve the public interests of their community. What is true of a single newspaper is equally true of a group. That chain operation makes for financial stability even critics of the system will admit. This is a matter of first-rate importance to the public which depends upon a newspaper for uncensored facts and free editorial elucidation of those facts. With financial stability and economic independence (granted the operation is in the hands of men whose sole interest is in journalism, men who are free from financial, social and political entanglements, as the successful group operators of the future are apt to be) comes a return of the fearlessness of the old-time editors of the days before the production of a daily newspaper became a great and expensive manufacturing job. . . . Chain newspaper development does not mean journalistic monopoly. It means elimination of economic weaklings; fewer but more virile ownerships. It means recognition of the passing of so-called personal journalism, which too often meant private journalism with private interests put ahead of public interests; private hates and private favors with partisan political obligations to be met before considerations of community service.

The indications are that, whatever may be thought of it, chain journalism has come to stay, though not to dominate. Such organizations as the Hearst newspapers, with 20, the Scripps-Howard with 19, and the Gannett group, with 17, seem firmly planted, and there are some 20 other large chains in the country.

Coöperative Journalism

Group or coöperative journalism is not confined to newspapers centrally owned and administered. There is not a daily newspaper in the country which does not benefit by news and feature services received on either a coöperative or a commercial basis.

The Associated Press. No journalistic enterprise in the world offers a better instance of a joint undertaking than the Associated Press, a mutual association with 1,367 member newspapers, 225,000 miles of leased wires, 2,000 full-time employees and 1,500 or more part-time correspondents. Every staff member of every associated newspaper, as well as the staffs of the principal foreign news agencies of the world, is a potential contributor to the Associated Press, so that it has been estimated that the organization has at least 80,000 individuals throughout the world at its call when need arises. The full daily wire service of the Associated Press reaches an average of some 150,000 words, or enough to make a novel of more than the ordinary length. Its annual expenses in 1939 totaled $10,891,000, the costs being met by assessments levied upon the member newspapers. Because of the diversity of its membership, every precaution is taken to avoid bias or partiality in the presentation of the news. Its work touches nearly every newspaper reader in the United States.

The United Press. The United Press, unlike the Associated Press, is organized as a profit-making corporation which sells its service. Like the Associated Press, it covers a world-wide field. At the present time it serves more than 1,200 newspapers, about 1,000 of which are in the United States, the remaining 200 being located in 42 foreign countries. In the United States it has more than 140,000 miles of leased telegraph wires, and its complete daily service runs to approximately 100,000 words.

The International News Service. The International News Service was organized by William Randolph Hearst to serve his own newspapers and to sell service to other newspapers. It serves several hundred newspapers and its daily report runs to 30,000 words.

Other news services. In addition to those mentioned there are a number of local and specialized news services in various parts of the country. In New York, for example, the Standard News Association covers Long Island and suburban New Jersey, and the New York City News Association covers Manhattan and the Bronx.

Syndicates and feature services. Feature and syndicate services enter largely into the make-up of the typical American newspaper, though they are used more largely in the smaller cities than in the greater ones. The Associated Press has for some years maintained a feature

service which includes such fields as sports, household economics, comment on events at the National Capitol, and news from Hollywood. The Associated Press also has a picture service and even sends out comic strips. United Features, a corporation largely owned by the United Press, issues pictures, comic strips, fiction, cartoons, and special "magazine" features. A large amount of feature material also goes out to newspapers taking the Hearst services.

In addition there are a large number of syndicates and feature services which send out material, sometimes in the form of "boiler plate," ready to print, sometimes in the shape of "mats," sometimes in printed form.

Advertising

The Audit Bureau of Circulations. Though advertising is at least as old as newspapers, it is only in recent times that it has become a well-organized business. Until the establishment of the Audit Bureau of Circulations in 1914, for the purpose of furnishing reliable facts about the circulation of newspapers and other periodicals, it was not always possible for an advertiser to know how many or what kind of readers he was reaching. Since 1914, and particularly since the end of the First World War, advertising has attained a degree of stability and reliability not previously realized.

Advertisements: a mirror of civilization. In a bookkeeping sense a sharp line must be drawn between news and advertising, since the one occupies space filled by the newspaper at its own expense, whereas the other takes a position bought and paid for by the advertiser. In another sense both advertising and news are "news." Neither would be printed unless it seemed certain that at least some of the readers of the newspaper would be interested in it. Both are keyed as expertly as possible to attract readers. A newspaper without advertising would seem bare indeed. In 1940, however, a new afternoon newspaper, *PM*. was begun in New York, with an avowed policy of carrying no paid advertising A glance at the files of 10, 20, or more years ago is enough to show how pricelessly advertisements will mirror our civilization for the eyes of future historians.

Advertising: its economic aspects. In its economic aspects advertising is the backbone of the newspaper "industry," as it is to a slightly less degree of magazine publication. That is to say, about two thirds of all newspaper revenues come from advertising. There has been a remarkable increase, especially since the beginning of the present century, in the amount of advertising space used, and a marked improvement in the artistic quality of advertising illustrations and layouts and in the integrity of advertising material. Many newspapers protect their readers by stringent regulations as to the kind of article that may be advertised and the claims that may be made for it. Some, like *The New York Times*, also have typographical regulations limiting the use of crude black areas in type and the use of illustrations in advertisements, and forbidding bizarre and freakish arrangements of type. The purpose of these regu-

lations is to insure, so far as possible, a typographically harmonious newspaper.

Advertising: its growth. The growth of advertising, both actually and in relation to circulation income, is illustrated by the following table showing newspaper revenues from 1914 to 1937, inclusive. The figures are taken from the Federal Census of Manufactures.

TABLE I

NEWSPAPER REVENUES FROM 1914 TO 1937

Year	*Subscriptions and Sales*	*Advertising*
1914	$99,512,000	$184,017,000
1919	192,820,000	373,802,000
1921	212,636,000	521,685,000
1923	222,560,000	580,938,000
1925	230,581,000	661,513,000
1927	252,811,000	724,837,000
1929	275,781,000	797,338,000
1931	261,569,000	624,954,000
1933	239,147,000	428,673,000
1935	260,224,000	500,023,000
1937	287,508,000	574,180,000

The depression which began in the fall of 1929 caused a decline in advertising, but the trend again is upward. Meanwhile, it is interesting to note that whereas subscriptions and sales in 1914 brought in nearly one half as much as advertising, they produced only a little more than one third as much in 1929 and in 1937 again returned to the proportion of one half. The newspaper reader was obviously becoming a more and more valuable customer.

A Modern Newspaper Plant

To make the picture as complete as possible, let us now consider how a representative newspaper is produced. The typical issue of *The New York Times*, which lies before us, has not only the local news of New York City and New York State but dispatches from Washington and other important American cities and almost every foreign city of note. A mass of information bearing on every activity of human life—on politics, finance, sports, society, shipping, international relations, the theater, and all the rest—has been gathered from far and near. There are notices of deaths, births, and marriages, tables of stock and commodity prices, and weather reports. We have before us a picture as complete as the keenest of human ingenuity can put together of everything important that a day has brought forth, whether conventional or matter-of-fact. An item may be as exciting as a detective story, as literal as a government report All legitimate tastes and needs are ministered to.

Naturally, this daily portrait of humanity and its ups and downs is

not turned out by hit-or-miss methods. We may make a skeleton outline of the newspaper process as follows:

1. Three kinds of "copy" are prepared: (*a*) the news; (*b*) the editorial page articles; (*c*) the advertising.
2. Copy goes to the composing room, where it is set into type and the type is assembled into page forms.
3. Page forms are transferred into "mats" and then, in the stereotyping room, into semicircular metal plates.
4. Plates are sent to the pressroom, where they are clamped on the presses, and the papers are printed.
5. Printed papers are sorted and routed in the mail room.
6. Papers are distributed to all parts of the world by wagon and train, by steamship and airplane, by every modern means of transportation.

To accomplish this huge task, the *Times* is organized into these departments:

The News Department, which gathers the news articles for each day's newspaper and prepares them for publication.

The Editorial Department, which devotes itself to the editorial page—the opinion as distinguished from the news.

The Business Department, whose work falls into 2 divisions: (*a*) advertising; (*b*) accounting.

The Circulation Department, which supervises the distribution of the papers to news dealers and subscribers.

The Mechanical Department, which handles the physical making of the paper in all of its stages.

The Promotion Department, which produces the *Times* advertising and circulation promotion.

The Personnel Department, which safeguards the welfare of the newspaper workers.

The Executive Department, which exercises a general supervision of the many operations that go into the production of the newspaper.

Let us now follow the route of the newspaper in the making.

The News Department. The central news mill into which the daily grist of happenings throughout the city, country, and world is poured afresh each day and night is the News Department. Here it flows in from widely separate and diverse sources and in various forms: cable, wireless, and telegraph dispatches; telephone messages from far and near; and finally the facts, as yet unwritten, brought in by reporters fresh from covering their assignments. All has to be organized, selected and classified as to its news value and proper place in the printed presentation next morning.

At the head of the news organization is the Managing Editor, whose field is literally the world—the physical world, the world of scientific discovery, the world of arts and letters, the entire daily business of man-

kind. Working under his direction, the News Department is divided into three principal "desks" and a number of specialized departments. The City Desk, over which presides the City Editor, handles local news. Domestic and Canadian news is handled by the Telegraph Desk, and wireless and cable news from foreign countries is handled by the Cable Desk. There are both day and night editors assigned to each of these three desks, and to each one of the night desks is attached a staff of copyreaders. In addition, there are the special departments: finance and business, sports, music, art and drama, real estate, and many others. The Sunday Book Review has its own staff, and the Sunday Editor, an important executive, supervises the Review of the Week, the Magazine, and the Music, Art, Drama, and Travel Sections.

The City Editor has under him over 150 reporters for general work and departmental news, and, upon call, some 150 suburban correspondents throughout the metropolitan district. He keeps a careful record of news events scheduled or expected to take place on a given day; he keeps a close tab on all the happenings recorded in his own and other morning and afternoon papers so that he may follow up a running story; and he constantly receives fresh news tips by telephone, by messenger, and by mail. Sometimes a day or more ahead, but more often not until the day before their publication, he assigns reporters to these stories. Each assignment, with the name of the reporter responsible for it, is entered on a schedule which, in the early evening, is turned over to the Night City Editor, who continues the same process until the paper goes to press.

As soon as they have completed their assignments, the general news reporters, together with the departmental reporters who have covered the courts, City Hall, political headquarters, ship news, and so on, report to the City Editor or to the Night City Editor, and typewrite their copy. Meanwhile, from correspondents, from news agencies, and by wire from all parts of the country, the telegraph news has been flooding in; and over the cables and by wireless, dispatches from the rest of the world have been flowing into the office.

Each news story is referred to the appropriate one of the 3 desks and its copyreaders. The function of the copyreaders in each case is to correct errors, condense when possible and desirable, eliminate possible libel and anything smacking of the editorial tendency—whether unfairness or bias—and write the necessary headlines. The edited copy passes for scanning to the editor in charge of the desk, next goes to the Control Desk, where an exact record is kept of the space used for each story and of the space alloted to each department, and then is carried by automatic conveyors to the composing room on the floor above. As there are at least 4 successive editions each night, it frequently happens that stories in the first edition must be condensed or even taken out in order to make room for more important news which comes in later.

The Editorial Department. Comment and judgment upon significant topics in the day's news appear on the editorial page. A council of the editorial staff, attended as well by the publisher and his executive assist-

ants, is held twice or more a week in the editorial conference room. Here the news is discussed and analyzed and the topics of leading interest or importance are selected by the Editor in Chief for assignment to the various editorial writers.

The completed editorial articles, after receiving the approval of the Editor in Chief, are sent to the composing room to be put into type and arranged in their proper places on the editorial page. On the same page are letters from readers and the briefer and usually lighter editorial articles under the head of "Topics of the Times."

The Advertising Department. While the News Department has been preparing for its huge quota of copy for the composing room and the Editorial Department has been engaged upon articles designed for the editorial page, the third type of matter that goes to make up the newspaper—the advertising—has been assembled.

A staff of advertising solicitors in New York and in offices maintained in other cities, all under the direction of the Advertising Manager, visits the local stores, the advertising agencies, and national advertisers to obtain display announcements. A special department of solicitors for classified ads keeps its corps of solicitors busy all day over the telephone wires. There are special advertising solicitors for rotogravure, financial, resort, and business page advertisements.

All advertisements offered for insertion are closely scrutinized for the honesty and propriety of their contents as well as for their typographical appearance. A special department looks after all cuts and layouts and makes suggestions for or insists upon such changes and improvements as to insure the publication of attractive cuts and a typographically harmonious newspaper as well. When the advertising matter has passed the test, it is sent to the composing room.

The Mechanical Department. From three sources—the News, Editorial, and Advertising Departments—the copy has flowed into the composing room. News and editorial copy goes first to the copy cutter, who distributes it, in the case of news, usually in short "takes" to enable a maximum number of linotype operators to work on each story simultaneously for speedy completion. About one half of the floor space of the composing room is devoted to the handling of news and editorial copy, and one half to advertising. In the "Ad Alley," the advertising copy is set.

The linotype, upon which most of the mechanical typesetting is done, is in reality a compact type foundry. The operator sits at a keyboard much like that of a typewriter, except that the letters are arranged differently. As he touches a key, a matrix, with the corresponding letter punched in its edge, is released from a magazine. These matrices are assembled in a line which is automatically moved to a position in front of a mold in which a "slug" of type is cast by an injection of molten metal. After an article has been set the type is assembled, proofs are taken, corrections are made where necessary, and the type is ready for its proper place in a frame known as a "form," equivalent to one page of the newspaper.

Meanwhile, in the other section of the composing room, the advertising matter has been set up and placed in the "forms," where it awaits the news type. The Make-Up Editor then directs the placing of the news type in the position he considers best for it in the printed page. In making up the first page, he follows the layout determined upon by the News Editor, who decides upon the news plan of the day after consultation with his executive assistants.

The size of each day's paper is determined by the Managing Editor early each evening after conference with the heads of advertising and the three news desks, each one of whom submits to him an estimate of the number of columns he will require to accommodate the day's news or advertising. If too much matter is at hand, it is the advertising, and in no case the news, surplus that is dropped.

After one of the page "forms" has been filled with type, a sheet of cardboard composition is laid over it and subjected to the tremendous pressure of a rolling machine. The result is a matrix or "mat," a mold in which each letter is represented by a depression. The completed "mat" is then taken to the stereotype room, where it is packed to prevent distorting, scorched to prevent breaking, bent into semicylindrical form to fit the shape of the printing press cylinder, and finally put into an "autoplate" machine, where a number of casts or "plates" are made. It is from these plates, metal replicas of the original paper mats, except that the type is now in reverse like looking-glass printing, that the newspaper is finally printed.

The pressroom, where the final processes of manufacture take place, is a place of thundering activity for about 5 hours each night. On an average week day, the *Times* has a net paid sale of 477,385 copies, and on Sunday a net paid sale of 802,386 copies. Parts of the Sunday edition are printed in advance, but the schedule never admits of any lagging. Men and machines alike must work with clocklike precision. The mere bulk of a great newspaper printing plant's operations may be imagined from the fact that the *Times* uses 110,000 tons of newsprint paper and 3,500,000 pounds of ink yearly.

When the stereotype plate reaches the pressroom it is clamped in its proper place on the big cylinders, and when all the plates are in place the presses are started. Paper is fed from great rollers, passing between cylinders in such a way as to be printed on both sides at once; and the printed "web" is then cut, pasted, and folded automatically, emerging in the form of completed newspapers.

New inventions, such as the "autopaster," which for the first time makes it possible to replenish the paper roll on a moving press without slowing down the press, are constantly adding to the speed and economy of operation. This device, installed first in the fall of 1931, embodies 47 different inventions of the maker, Henry A. Wise Wood. One of the *Times* presses weighs 92 tons, is made entirely of steel, and has an estimated capacity of 50,000 papers an hour of any size up to 32 pages. The *Times* pressroom in Manhattan is capable of producing 554,000 complete 32-page newspapers an hour.

The Sunday edition. The Sunday edition passes through the same mechanical processes as the daily edition, except that the *Times* Magazine Section, Book Review, and the picture sections are printed by an intaglio process on rotogravure presses. The special sections of the Sunday edition are produced under the direction of individual editors, each with a staff of subeditors and contributors of his own. The Sunday *Times* aims to present the background of the news, in book reviews, in the dramatic pages, in the pages devoted to aviation, automobiles, real estate, fashions, and general business, in the illustrated rotogravure sections, and in magazine and feature articles. The magazine and feature articles attempt to explain and interpret topics which have been prominent in the news. Some are written by members of the Sunday staff or are submitted by professional writers and reporters, while many others are the work of men and women conspicuous in the world's affairs for activities other than writing. In its methods of securing material for its articles, in its world-wide contacts, and in its systems of copyreading and editing, the methods of the Sunday Department resemble those of the News Department. The main difference is that though the chief emphasis is on facts, interpretation plays a larger part than in the daily news stories.

Mailing and distribution. The final steps in getting the newspapers to its readers are taken by the Circulation Department. As soon as the printed papers are off the presses they are carried by wire conveyors to the mailing room. From this room most of them are distributed in bundles to newsdealers and news companies. (Automatic machinery plays a large part in the bundling and wrapping.) The bulk of the output goes by auto truck to dealers within a 60-mile radius of Times Square. Outside this radius the papers are ordinarily sent by train, either in bundles to dealers or in copies mailed to single subscribers in the United States and abroad. Delivery is also made by airplane.

Such, in briefest possible outline, is the story of the way in which one newspaper, in a miraculously short space of time, turns out its hundreds of thousands of copies. We have not stopped to look into the telegraph room, with its ever busy instruments; the radio room, which is in constant touch with stations and ships all over the world; or the "morgue," in which are kept hundreds of thousands of clippings, with a cumulative index going back to 1905. Nor have we been able to visit the great paper mill at Kapuskasing, in northern Ontario, of which the *Times* is part owner and the major part of whose annual product goes to the *Times*. But perhaps we have seen enough to realize that getting out a metropolitan newspaper is an enterprise of no small magnitude.

The Future of the Newspaper Industry

Newspaper business, whether in the case of the great individual newspapers, of the "chains," or of the news-gathering and fact-gathering agencies, has undeniably become "big business." There is no probability that it will ever become small business again. We may think of

the future in terms of mechanical improvements and in terms of the cultural significance of the newspaper.

No one can safely predict what invention will achieve in the gathering and dissemination of the news. Probably the processes involved will be still further shortened. The completed newspaper will probably be sent farther and faster than it is today. That the newspaper will ever be displaced by the radio or any similar invention may be doubted. An essential quality of the newspaper is that it is a permanent record from which the reader may select what he likes. This permanent record may some day be impressed upon some material other than newsprint by some means other than the present-day printing press, but it will still be a newspaper and the present-day principles of sound journalism will still apply to it.

The newspaper is, and must be, a cultural agent. On the whole, American newspapers are now better equipped to fulfill this function than they were a generation ago. They are more complete, more accurate, less affected by the prejudices of individuals. Newspapers have grown better because the public has been educated to demand better newspapers, and because no newspaper, in the long run, can survive and prosper without public confidence. The great newspaper is "affected with a public interest," and this truth is being more and more realized both by publishers and by readers. While mankind retains a spark of interest as to what is going on in the world, the newspaper, in some form, with whatever mechanical and scientific aids are available, will survive. As long as there is a food industry or a building industry, there will be a "newspaper industry."

9

The Textile Industry—Cotton from Prehistoric Times to 1930

Cotton in Prehistoric Times

An ethnological mystery. The history of cotton begins with an ethnological mystery. Cotton occurred in prehistoric times in three continents: Asia, South America, and North America; and there is no scientific evidence to establish positively any one of these areas as the original source. The generally accepted literary and academic belief points, of course, to Asia, since all other records of human culture there are immensely more remote than in the New World. In addition to this is the unquestioned fact that human life came to the Americas from Asia in a series of waves of immigration and at remote and various periods of time. Man is not a native of our fauna; nor have we yet found in the fossil remains of the American continent any evidences of the earliest forms of the human race. The assumption, therefore, is that the immigration from Asia was, relatively speaking, at the higher levels of human culture. But this by no means proves the assumption of the priority of the use of the cotton fiber in Asia as opposed to the New World.

For many years, moreover, authentic specimens of cotton lint, yarn, and fabrics have been discovered in widely scattered grave sites in North, Central, and South America. Conservative archeologists have attributed to many of these specimens a considerable antiquity, and most of these ancient specimens show an extremely high degree of technical and artistic skill and, by inference, considerable agricultural knowledge. Museums and private collections, here and in Europe, are rich in splendid and growing collections of these amazing works of art. From the diversity of the specimens discovered, the intricate nature of their construction and decoration, the difficulties of desert cultivation, and the extent of the contiguous cotton area in the New World—from the central portion of Chile to the salt mines in northern Utah—we may reasonably assume an antiquity for the first use of cotton infinitely more remote than the theoretical dates of the actual specimens so far recovered from the grave sites. The dawn of a new technic does not reveal such intricate perfection of detail as these documents attest.

In addition to this unimpeachable evidence, there are extensive and accurate records of the Spanish commentaries as to the skill and artistry of the natives in the fabrication of cotton fabrics in practically all areas of their conquests. Columbus sent back to Spain cotton yarns and fabrics from his first contacts in the Caribbean; and on the strength of his findings he argued eloquently, if inaccurately, that he must have discovered India, since to his mind—as to the mind of the average Spaniard of that day—cotton was an Indian product.

Have we perhaps fallen into the same error and accepted with too great haste the assumption that cotton must originally have been cultivated in Asia and transferred to the New World as a culture trait?

Earliest known cotton discovered in India. Until recently, there was no physical evidence from Asia to prove that cotton was more ancient than the sixteenth century; but recently a small fragment of cloth, perhaps three eighths of an inch square, and a few fragments of yarn oxidized in the handle of a silver vessel, excavated from ruins in the Indus Valley, have been discovered to which credible authorities have ascribed an antiquity somewhere between 3000 and 3500 B. C. Aside from a 16-ply yarn, which suggests great skill in spinning, there is nothing in these fragments to indicate the breadth and extent of technics found in the fabrics of the New World. But at least the physical character of the cotton, as determined by microphotography, is little different from the varieties and types of cotton still grown on the plains of India.

Cotton in prehistoric America. As yet, we have found no cotton in the New World which approaches within 1,000 years this venerable antiquity; but cotton has been discovered in a cave in Grand Gulch, Utah, wrapped around a naturally dried body, in the form of an intricate tapestry apron, in geometric symbolical design, representing a civilization that had completely passed away from this semidesert region before the dawn of any known culture.

Opinions vary as to the age of this fabric, and the hesitation and modesty of American archeologists are well illustrated in the dates ascribed. These estimates vary from 1000 to 2000 B. C. A portion of this fabric is in the Museum of Natural History in New York City; a second fragment is in the Museum of the American Indian; and a third fragment is in the author's collection. The technical skill involved and the artistic certainty of pattern mark this fabric as a finished example, not as a crude beginning of an art.

Other fragments, showing interesting and well-organized designs worked out in human hair on a cotton background, have recently been unearthed in the salt mines of north-central Utah; and there is reason to believe that these are even more ancient than the interesting specimens unearthed in Grand Gulch, Utah. A loom containing a partially finished web of cloth from the same general area is of the type universally associated with cotton.

Nor are these the only reminiscences or records proving that the cultivation and fabrication of cotton lint were well known in these regions, perhaps as early as the second millennium B. C.

It is a curious fact that the basic technical principles of spinning and the basic loom types are identical in the ancient cotton areas of the New World and Asia. In both areas occur every type of fabric and method of decoration. This situation has led many thoughtful students of culture to the assumption that, at some remote period and from some undetermined area, cotton culture and technics spread from Asia to the New World.

This assumption is difficult to support, since none of the food plants of Asia occur in the highly developed horticultural science of prehistoric America; nor do any of the domestic animals of Asia, the wheel, iron, and so forth. But the bow and arrow are believed to have spread from Asia to the New World, and therefore why not the loom, the spindle, and the cotton fiber?

In Professor Roland B. Dixon's splendid book, *Building of Culture*, he treats the subject of intrusion of material culture from Asia to the New World with high scholarship and disapproval. The only hesitation or doubt in his presentation is involved with the textile complex in these two remote areas.

Recently, however, the botanists have come to the aid of the ethnologists, and have determined by long and patient experiments that the true Asiatic cotton and the true cotton of America are apparently distinct botanical species. In the seed cell of the Asiatic cotton, there are only 13 chromosomes; whereas, in the seed cell of the American cotton, there are 26. They have almost decided to give these plants distinct scientific names. Is there significance, perhaps, in the fact that the number of chromosomes in the Asiatic seed are just half the number in the American seed? And does this numerical difference represent a variation that may have resulted during a long period of time and change of environment; and does it, therefore, support even more strongly the idea of original intrusion? This assumption, however, is speculation on a dangerous premise. No one is willing to assume an antiquity sufficiently remote for highly developed cultures in the New World to account for this botanical change.

On the other hand, a strong prima facie case may be made out for the appearance of the cotton plant and the independent evolution of technics in both continents. For example, it is well known that all primitive people seek with extreme earnestness for filatory elements. It is a quest almost as eager as the quest for food or decoration. This search has covered every conceivable phase of nature, and has discovered and made use of a vast number of different raw materials. If, therefore, two peoples, remote in time, culture, and geographical position, should have chanced in nature upon two similar hair seeds, and have attempted to create from these yarn and cloth, they would have been met by the same technological difficulties. Later, the author hopes to establish the fact that the peculiarities of the cotton fiber determined both the types of loom and spindle, and the methods of spinning and weaving used in these difficult operations. Through elimination and experimentation, two peoples might have arrived at the only possible technological solu-

tions of their difficulties, and through comprehensive trial-and-error experiments in technological methods, they might have reached the same group of results through technological exhaustion. This fact does not, of course, imply any similarity in design or a parallel emphasis on technics. That we have not added a single new fundamental technic to the spinning and weaving of cotton or to the decoration of fabrics since these craft ages seems strongly to support this assumption. But the idea should be regarded only as an assumption, strongly shaded on the side of probability. New archeological discoveries may at any time occur which will reinstate the more romantic theory of intrusion of material culture or diffusion from a common center.

In the prehistoric grave sites of the deserts of coastal Peru have been found every type of woven fabric and every method of decorating a web of cloth known in any other part of the world or at any other time. While wool and human hair were largely used, the culture is fundamentally that of cotton. If there were no other record of yarn spinning or cloth weaving by which to be guided except those found in prehistoric Peru, every type and technic of cloth making known today could be restored.[1]

Structural similarities of prehistoric and modern cotton. Consider for a moment the physical peculiarities of cotton lint: It is a seed hair, like other plumose varieties, evolved in nature to aid in the wider distribution of the seeds at maturity. It has one peculiarity, however, of the utmost importance. The cotton fiber is a flat tube, which is attached to the seed. It is open at the butt end and sealed at the tip. This canal contains a certain amount of vegetable oil, which, upon maturity, flows back into the seed; and since the walls of this canal are of unequal thicknesses, the ripened fiber collapses in an irregular manner and forms half-twists, or kinks, which produce the friction surfaces necessary to make the fibers adhere through the act of spinning.

This quality is not defined so well in wild cotton as it is in cultivated cotton; nor is the degree of spirality as essential in hand, as opposed to machine, spinning. But at some place and at some time, it must have been sufficiently defined to have attracted primitive man in his quest for spinnable fibers and to have been accentuated later through selective breeding, until the quality became fixed. If cotton were cultivated for lint alone, the increase of lint compared to seed would naturally increase this spirality. There are slight structural differences between prehistoric cottons and modern cottons; but taken as a whole, the same physical qualities appear in the cotton recovered from grave sites as are found in the cotton fields of today.

Fundamental methods of spinning. The later introduction of the spinning wheel in India somewhat obscures the fact that the fundamental methods of cotton spinning in Asia and the prehistoric cotton areas of the New World are mechanically identical. Even after the wheel was

---

[1] See Crawford, M. D. C., "Peruvian Textiles" and "Peruvian Fabrics," in *American Museum of Natural History Anthropological Papers.*

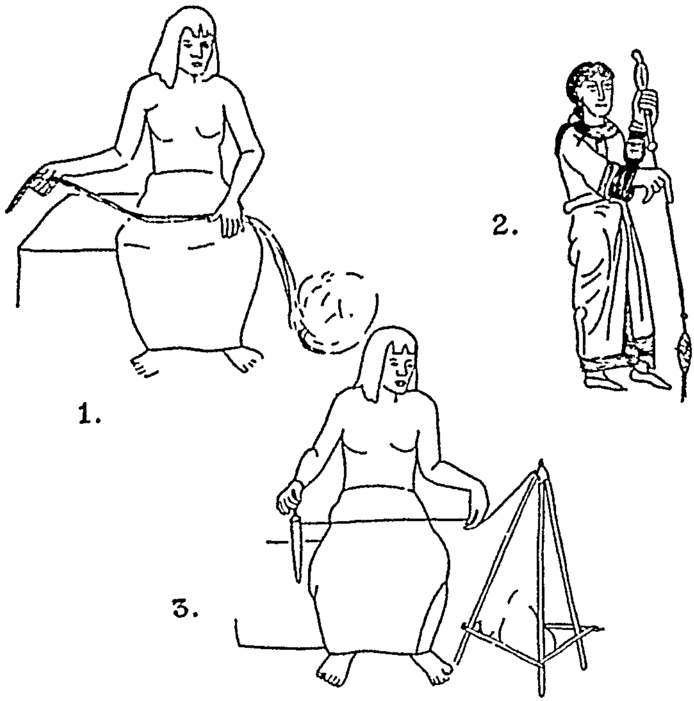


Fig. 1 Three primitive ways of spinning. (1) Rubbing on thighs; (2) suspended whorl, (3) Cayapa Indian spinning, with spindles resting on friction-reducing surface.

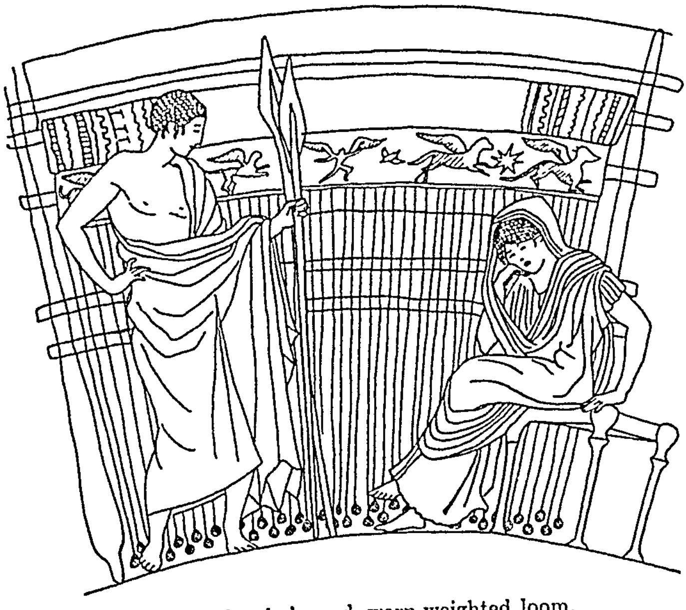


Fig. 2. Single-barred, warp-weighted loom.

in use for the coarser yarns, the spindle, with one point resting on a friction-reducing surface, was employed to make the exquisitely fine yarns used in the gossamer Dacca muslins. It is the author's belief that this earlier method is comparable to the technic of ancient Peru and that the method employed in primitive cultures is still in existence.

There are three fundamental methods of spinning (see Figure 1), all of which are still practiced by primitive people and have an amazing antiquity. The first and earliest is the rolling of fibers on the naked thigh; the second is the completion of the spinning process by the aid of a rapidly revolving suspended weight, known as the "distaff and whorl" method.

This second method is generally applicable to bast fibers, such as hemp, flax, ramie, and jute, and the coarser wools. It was the method used in Greece and was once common throughout Europe. To the author's best knowledge, this technic is never applied to cotton, except where there is evidence of intrusion; and it can never be applied to the finer counts and types of cotton yarn, because the shortness and weakness and irregularity of the cotton fiber prohibit the use of a technic which accentuates, rather than controls, vibration.

The third method—the earliest recorded form of spinning in India—consisted of a spindle, one point of which rested on a friction-reducing surface, while the thumb and forefinger of one hand gave it a steady rotary motion and the other hand elongated and twisted the soft, partially formed yarn or roving into yarn. This was unquestionably the method pursued in the spinning of prehistoric Peruvian cotton, as all of their delicate palm-wood spindles show at one end that polish which could only have been the result of contact with some smooth friction-reducing surface. Shells, pottery, and wooden bowls are a part of each spinning basket found in the graves. The Cayapa Indians of Ecuador still practice a method which, with slight variations, must have been the universal practice in Peru and in India before the Spanish intrusion in the former region and the introduction of the spinning wheel in the latter region.

A comparison of cotton-spinning methods in the different world cotton areas, ancient and modern, suggests a similarity that can be accounted for as the most logical technical solution of spinning this difficult fiber, even while such a similarity of process implies cultural contacts. At least, the technological explanation avoids many difficulties and scientific uncertainties incident upon the intrusion explanation.

Early looms. Early looms of Egypt, Mediterranean races, northern Europe, England, Iceland, Alaska, and the prehistoric Swiss Lakes were the single-barred, warp-weighted type (see Figure 2), beautifully illustrated on Greek vases and proved by the warp weights found in the predynastic Egyptian graves and in Asia Minor. This loom is, with a single interesting exception, associated with either bast or wool fibers, or both. The single-barred loom is never associated with cotton in any part of the world or at any time. It has remained unchanged for nearly 7,000 years and is distributed over three continents. Apparently it has offered no possible mechanical growth. The single-barred loom has an apparent

association with the bow and arrow, and, with the bow, was evidently introduced from the Old World into Alaska, where it is still used to weave. It can be said that the two-barred loom (see Figure 3) covers the cotton area of the New World, from Peru northward through Central America, Mexico, our own Southwest, and into the northern central

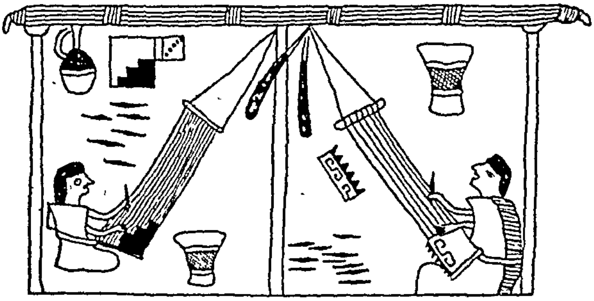


Fig. 3. Two-barred looms

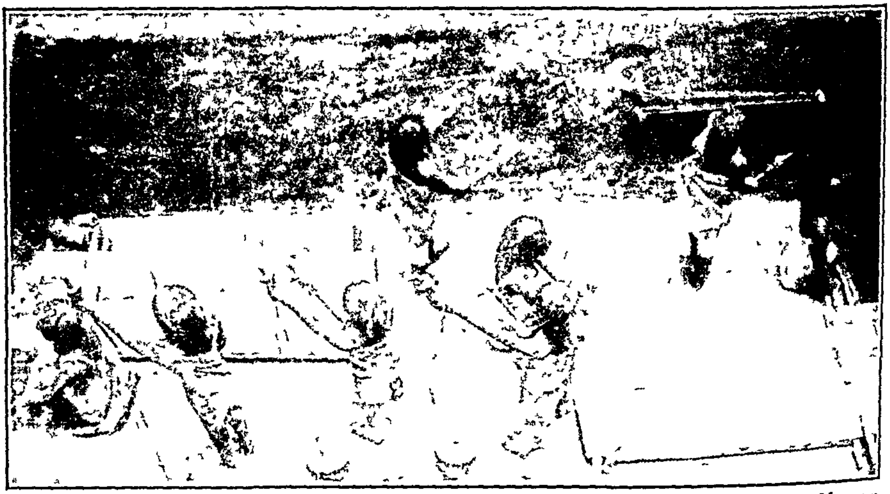
limits of the state of Utah. There was a seepage of this technic into the South American jungles, but the two-barred loom does not occur anywhere else in North America, except in a modified form of a bag loom among the Salishan people of our Northwest.

The cotton area of the New World in prehistoric times seems seldom, if ever, associated with the technic of the bow and arrow; it seems difficult to imagine how any primitive people who depended largely on the chase for food could have abandoned as useful an implement as the bow in exchange for a more rudimentary type of spear thrower, and, at the same time, could have exchanged a primitive for a more complex loom.

These suggestions seem generally to support the idea of intrusion via the Pacific. They are not, however, advanced as proof but merely as an effort to cover the entire body of evidence in the limited space that this phase of the discussion deserves. A technological explanation of this loom similarity, however, is possible. Cotton fibers and yarns are more pliable and permit of a greater refinement in spinning than any other natural fiber. The purpose of a loom is to keep the warp—that is, the threads that run the length of the fabric—parallel to each other and at a reasonable degree of tension for subsequent manipulation in weaving. It will be obvious to anyone who gives the matter consideration that a single-barred loom, where the warps are paralleled and kept at tension by weights attached to small groups of warps, would not be an adequate implement for the weaving of fine cotton yarns. Nor is it too great an exercise of technical imagination to assume that it might easily have occurred to two weaving people to add a second bar to the loom when they encountered the cotton fiber, without any cultural contacts to explain the intrusion.

The only exception to finding a two-barred loom in association with any fiber other than cotton occurs in Egypt. A two-barred loom was recently discovered in a tomb in Thebes, dating back to about 3500 B. C.

This is in the form of a grave model, showing not only looms in position for weaving, but the preparation of warp yarn to be placed in the loom and the spinning processes. From that time on, illustrated Egyptian looms were of the two-barred variety (see Figure 4). But the older type of loom in Egypt was the single-barred variety, as evidenced by the warp weights in the more ancient tombs; and primitive cultures still in existence on the upper Nile use single-barred looms. Trade in sailing boats between India and Egypt is known to have existed as early as 3000 B. C., and it may well be that the two-barred loom was an intrusion from some part of Asia open to this commerce.



Courtesy Cairo Museum

Fig. 4 Egyptian weaving—Cairo, 3500 B.C.

On the other hand, the technological explanation may be that Egypt, as early as 3500 B. C., had already developed a high degree of perfection in spinning the finer types of flax yarns; and a very fine filament of flax would be almost as pliable as cotton and would therefore have required the two-barred, rather than the single-barred, type of loom for successful weaving.

Dawn of the Modern Use of Cotton in Europe

The textile arts of Europe, of which our own are a repercussion, are practically without exception the result of Asiatic intrusion. It must be remembered that the two-barred loom and wheel are of Asiatic origin. Wool and flax were, of course, native European fibers. We find them fabricated into intricate cloths in the Swiss Lake civilizations in neolithic times, perhaps even earlier. But wool and flax, during historic times, were spun and woven in Europe on Asiatic, not on European, principles and implements.

Routes of textile intrusion. The general routes of textile intrusion from Asia to Europe were through the great cities of Byzantium and

Alexandria to the islands of the Mediterranean; eventually, at the dawn of the Renaissance, into Italy; and gradually into northern Europe There was another current of intrusion through the Mohammedan invasions along the coasts of Africa and eventually into Spain. But while a high degree of technical skill in the fabrication of silk and cotton occurred in Spain, religious differences and a perpetual condition of warfare on the northern frontiers prevented their penetration into Europe.

In all of this vague record of commerce and technology, there is a thin trickle of cotton. Certainly cotton was used as a wool adulterant in Italy as early as the twelfth century, and all-cotton fabrics were manufactured in Spain at an even earlier date. There are records of cotton lint being imported into the English monasteries in the twelfth and thirteenth centuries and used for candlewicks and also as a wool adulterant in the fustian cloths. But cotton only becomes important in European commerce and technology with the discovery of the water route around the Cape of Good Hope by Vasco da Gama, in 1497.

Effect of discovery of all-water route to the Orient. The year following this memorable voyage, a Portuguese commercial venture returned from the Orient with a cargo of spices and a heretofore unknown article of commerce, known as *"pintadoes,"* or painted cottons.

The effect of this journey was to open trade in the Orient to Portuguese energy and, by so doing, to diminish the commercial importance of the great Italian trading cities, which had used the older land and water routes to the East, until they fell under the control of the fanatical Turks in 1452.

The discovery of an all-water route to the Orient not only cheapened Oriental products in Europe but very rapidly absorbed the trade with the East that the Italian cities had monopolized for centuries. This had two direct influences related to the subsequent cotton development in Europe: (1) it introduced painted or printed calicoes, and hence the desire for color, to a very wide market; and (2) it forced the Italian cities to rely on their native ingenuity as manufacturers of merchandise rather than as international merchants.

The Calimala Guild in Florence had been engaged for at least 3 centuries in the importation of raw wool from England, to be fabricated into cloth in Florence, and also in the importation of rough homespuns, to be dyed and finished in Florentine mills This association between England and Italy was certain not only to have affected English ideas on international business and banking but also to have left some technical germ which was later to bear fruit in the mechanical phases of the Industrial Revolution.

Contributions of Leonardo da Vinci and Johann Jurgen. The most important of later cotton inventions—an invention without which it is difficult to see how the mechanical phase of the economic revolution could have occurred—can be traced to a sketch, or rather a diagram, of a device to spin cotton fiber found among the mechanical drawings left by Leonardo da Vinci (1452 to 1519). During the life of this great Florentine, no model of this sketch is known to have been produced. It was

apparently too far in advance of the technical knowledge of his own time to be of value. But 50 years after his death, this sketch came into the possession of Johann Jurgen, a wood carver of Wattenbuttel, in Brunswick, who modified its form, produced it in wood instead of metal, and attached it to the Oriental spinning wheel, which, with this addition, became known as the "Saxony" or "Brunswick" spinning wheel,[2] an object familiar to all collectors of antiques.

The device consisted of a spindle with a hollow jacket, both of which operated at different rates of speed, with the partially spun roving twisted around one end of the flier to create friction. Draught was created by the difference of speed between the jacket and the spindle. This wheel was the first used in Europe that made possible the spinning of cotton threads of any strength, since the European spinners lacked the skill of the East to produce cotton-warp yarns on the plain Asiatic wheel.

In Arkwright's memorable invention, to be later described, the principle of this flier appears, and it more closely resembles Leonardo da Vinci's original drawing than the earlier modification of Jurgen on the Brunswick spinning wheel. It is not too great a stretch of the mechanical imagination to claim that da Vinci's idea was the technological starting point for all modern forms of cotton machinery and, consequently, to designate it as the mechanical starting point of the Industrial Revolution.

England's renewed interest in Oriental markets. England's first direct interest in the Oriental trades developed after the defeat of the Spanish Armada had proved to English sailors that they had nothing to fear from the Spanish mastery of the ocean. They discovered that their light, compact privateers were more than equal to the cumbersome merchantmen and men-of-war of the Spanish navy.

England's first participation in this trade began significantly in an act of piracy, when her privateers, in 1592, captured the *Madre de Dios*, a Portuguese carack, returning from the Oriental markets. Her cargo of calicoes, linens, quilts, carpets, and spices, together with jewelry and other rich commodities, aroused great interest in England; and in 1599, the London East India Company petitioned Queen Elizabeth for a charter, which was granted a year later. In the early business of the great East India Company, cotton played only a minor role, the main interest being in spices. England had nothing to exchange with the East that the East was willing to accept, and consequently she had to maintain the trade relationship with silver.

Early block printing. England's early efforts in the Oriental markets were confined to purchasing cotton fabrics on the mainland of India and taking them to Java to trade for spices. For at least half a century of this early trade, English ventures concerned themselves largely with acts of piracy in the Indian seas against the Dutch, the Portuguese, and the natives, with apparent equal indifference as to the properties involved but with a shrewd eye for piratical opportunity.[3]

---

[2] See Usher, A. P., *A History of Mechanical Invention* (New York: McGraw-Hill Book Company, 1929).

[3] See Craik, *History of British Commerce.*

The influence of the importation of calico on English commerce and industry was soon felt. In an effort to protect the silk, woolen, and linen business of England, a law was passed as early as 1700 prohibiting the importation of Indian calicoes. Subsequent modifications of this law will be referred to later; at the time, no all-cotton goods were produced in England, and cotton itself was only used as a wool adulterant, although a printery had been established near London in 1696 with French Huguenot labor and capital, where Indian bleached cotton goods were printed by hand blocks, and later linen-warp and cotton-weft goods were so processed.[4]

The art of printing fabrics is an offshoot of block printing on paper developed in the early centuries of the Christian era in China and introduced by the Arabs into Egypt, India, Spain, and Italy. It is a part of the story of papermaking. Paper and block printing appeared in the Samarkand in 751; the conservatism of the Mohammedan, however, did not encourage the use of block printing in the art of bookmaking, but diverted this technic to the printing of textiles, particularly cottons, for decorative purposes. Doctor Carter, in his *History of Printing and Paper,* mentions the fact that the poorer Mohammedans in Egypt printed certain verses of the *Koran* on paper for charms and amulets, but the great use of the device of block printing grew up in connection with the cotton prints of India.

Printed cottons are mentioned by Reifstal as occurring in Egypt during Roman times, although he does not mention any specific specimen as still existing in a museum.

Paper, which is of Chinese origin, reached Europe through Italy in the thirteenth century; it reached Spain a century earlier because of her Mohammedan contacts. Direct printing with pigment colors and designs outlined in ink from blocks was known in Europe in the thirteenth and fourteenth centuries, and perhaps even earlier in some of the monasteries.

Cennino Cennini (born in 1372) describes the technic of block printing in Italy; but her printing can in no wise be compared with the Indian printing, particularly in the technic of dyes and the use of resistant technic and mordants.[5]

English Textile Labor

England early encouraged manufacturing. Ever since the Norman kings, there had been attempts made to colonize textile populations from the Continent, and England's supremacy in the world's wool market was a constant inducement for the British Government to encourage the manufacture of fabrics at home. But only the coarser fabrics were made in any quantity in England, and the vast majority of these were shipped abroad to be dyed and finished.

Sheep raising profitable. England's freedom from internal strife, as

[4] Baines, E., *History of Cotton Manufacture in Great Britain.*

[5] Baker, G. P., *Calico Printing and Painting in the East Indies in the XVIIth and XVIIIth Centuries.*

compared with the Continent, and the fact that she was unembarrassed by internal and local tariffs, made sheep raising a comparatively profitable venture and thus brought her in contact with the great textile industries of Flanders and Italy. But there is little to prove that she had made much progress in anything beyond the ruder textile arts, up to and including the seventeenth century. The Black Death, which is supposed to have killed from one third to one half the population of England, had a powerful influence in increasing sheep raising as opposed to agriculture, since it was no longer possible profitably to cultivate farms with hired labor because of the high wages. Many estates were therefore turned into sheep runs.

England's backwardness in agriculture, as compared with the Continent, further emphasized this situation. At the time of Elizabeth, when the change in agriculture began and when enclosed fields began to take the place of the common land, there was already the beginning of an unemployed—almost unemployable—moiety of the people, which made it a comparatively simple matter to begin the mercantile system of production, depending, as it does, upon a surplus of labor population.

Spinning a home industry. Spinning remained, up to the beginning of the great inventions, a home industry, as the word "spinster" implies It has been estimated that it accounted for at least 25 per cent of the cash income of the smaller artisans and agriculturists.

Weaving becomes a professional industry. Weaving had become, at least partially, a professional industry. Weavers bought yarns independently, made cloth, and sold it to merchants; or merchants gathered a number of weavers either under one roof or under one control and paid piece-rate wages and owned the looms. They distributed fiber of wool, cotton, or flax to the spinners; gathered groups to prepare fiber and roving; collected the yarn and brought it to the weavers; purchased the cloth, had it finished by professional dyers and finishers, and redistributed it at wholesale and retail. In other words, the social structure of industry was already set and the factory system installed before the first machine was invented.

Far-reaching effect of English law on labor. It remains only to explain one law in England that preceded the invention of machinery but that had a profound influence on the later social welfare of workers in the machine industries.

In Elizabeth's time, an effort was made to control the fluctuation in labor prices and perhaps to protect labor from exploitation. The introduction of vast quantities of silver—one of the results of the romantic Spanish Conquest—had increased the amount of silver coinage in circulation four times by the first quarter of the seventeenth century England, through the wool trade and through privateering, had absorbed a fair amount of this precious metal. In consequence, the money costs of living—as expressed in wheat and barley, meat, and rents—had risen in England, wages had not followed in proportion, and agricultural labor was extremely restless.

A law, which was the predecessor of the modern dole, was then passed,

authorizing the justices in each Quarter Session to establish a theoretical living wage based on the price of wheat and, where the wage of any individual chronically fell below this level, to supplement it from the poor rates of each parish. At a later date, when the development of machinery and water power, and ultimately, of steam, drew the textile industry—particularly the cotton industry—to the midlands of England, the fact that each parish was responsible for its poor had a profound, far-reaching, and terrible influence on the development and exploitation of child labor. Each parish, anxious to relieve itself as far as possible of its poor rates, gladly accepted the opportunity offered by the rising manufacturers in the midlands to send them all children who were on the rates There are contracts in existence in which mills agreed to take 1 idiot with every 19 sound children.

The Industrial Era

Demand for fabrics. Before the dawn of the industrial revolution, the textile trades were already well organized and highly specialized, at least in weaving, dyeing, and finishing. England's coarser woolen fabrics and wool staples had long been objects of Continental trade; and there had sprung up a demand for lighter fabrics, color, and design inspired by the introduction of Indian calicoes. This demand had been met in part by the establishment of block-printing plants using plain Indian calicoes and also cotton-weft cloth with linen warps. In 1685, the revocation of the Edict of Nantes drove to England thousands of skilled French textile workers, and many merchants and capitalists interested in the textile industry Silver had increased in circulation, making possible the building up of capital funds for commerce and industry, and England's war boats had successfully established their supremacy and her armed merchantmen had penetrated the seven seas in quest of spoil and commerce.

At the beginning of the eighteenth century, there was a period of strong prosperity in England, owing to the changes in agriculture, her rapidly expanding oriental trade, the increase in circulation of silver from the Spanish colonies, and the rising wealth of her colonies. This condition created such a demand for fabrics that the home spinners were swamped with orders, and weavers were forced to pay a premium for yarn.

John Kay's fly shuttle. Just at this time, in 1733, occurred the first great invention—John Kay's fly shuttle (see Figure 5)—that increased the productivity of the loom and still further increased the demand for spinning. John Kay, of Bury, was a weaver of broadcloths—that is, cloths so wide that a man could not throw the shuttle between the sheds of the warp without help. In making this type of cloth, a weaver had to have one assistant, and sometimes two, to cast and catch the shuttle. Kay's invention consisted of two blocks of wood and leather, connected with cords to a handle convenient to the weaver's hand and moving on fixed rods, which made it possible for a weaver—as an incident to opening and closing the warp sheds and driving home the reed—to propel the shuttle between the open sheds of the warps.

Kay was driven into exile by the enraged labor, who saw in his machine a fertile source of future unemployment. He died in poverty and misery in Paris, leaving as a heritage the loom, which was from three to four times as productive, in relationship to the unit of labor, as it had been before his invention. And as it came at a time when yarn was already scarce, it vastly stimulated the first impetus toward the spinning inventions.

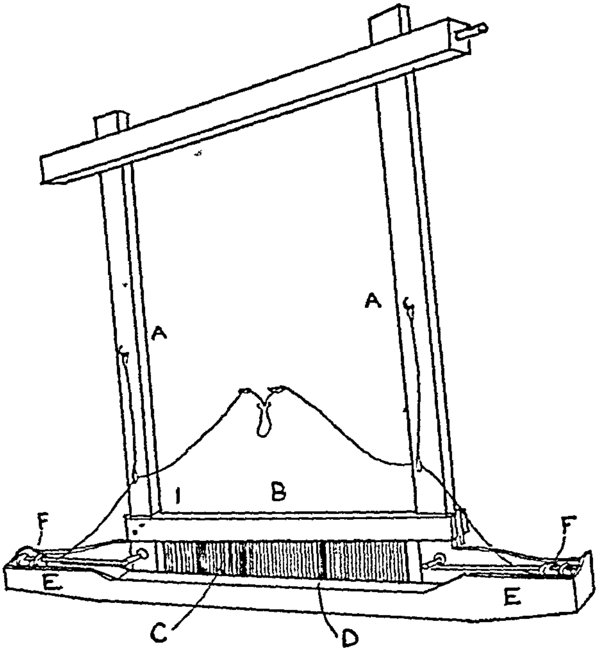


Fig. 5. Kay's fly shuttle.

James Wyatt's roller spinning. The first visible spinning invention of importance was that of James Wyatt's roller spinning in 1737. It is the author's belief that this invention had its inspiration in the metallurgical industry, and it seems undoubtedly to have been an Italian repercussion in England. The principle involved is that of two sets of rollers, the bottom set fixed, the top set held in loose leather bearings, and each set revolving at progressive degrees of speed, attenuating and partially twisting the rovings—that is, the partially prepared yarn. Wyatt's machine did not complete the spinning process but was a supplementary, or preliminary, process that at first did not seem to have had any particular technological significance.

The first cylinder carder. A year later, in 1738, Lewis Paul invented the first cylinder carder, which still further simplified the preliminary processes of fiber preparation; in 1748, he improved this card. The cards of today are among the most notable and perfect of all machinery and can be directly connected with the principles evolved by this inspired mechanic. The process of carding, formerly performed by hand wire

brushes, is intended to place the cotton fibers parallel to each other and ready for spinning.

During the next 20 years, there were undoubtedly many experimental improvements and modifications of these original inventions, many of which have disappeared. Jedidiah Strutt's invention of the derby-rib appliance for stocking weaving, in 1752, which diminished to a certain extent the companion industry of home knitting and which still further reduced the cash income of the small independent farmers and increased the growing unemployment is also of significance. But the greatest change was further to accentuate industrial organization and still further to prepare home workers for factory production.

The first spinning jenny. In 1764, James Hargreaves produced his first spinning jenny (see Figure 6). This device made it possible to spin

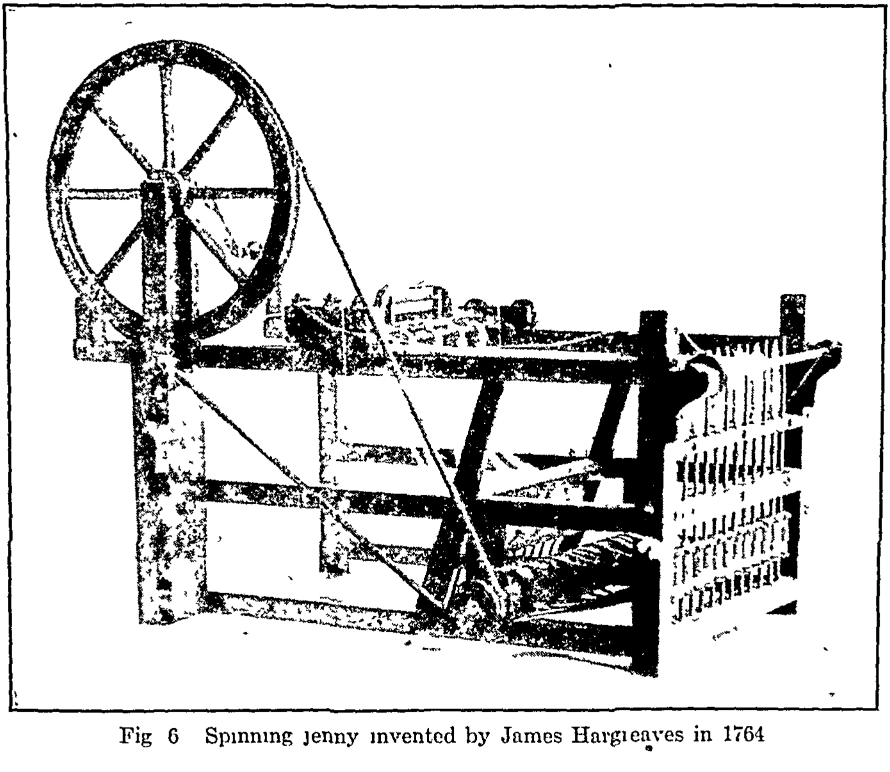


Fig 6 Spinning jenny invented by James Hargreaves in 1764

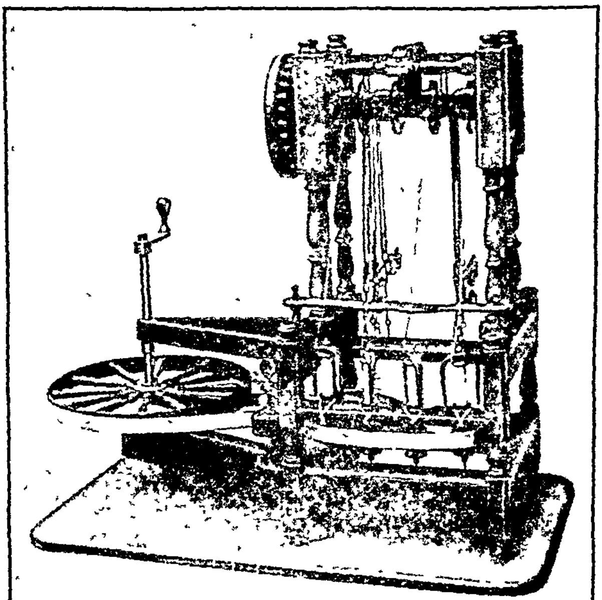
coarse cotton yarns, weak in structure but suitable for weft yarns. It originally contained 8 spindles. Very soon, this machine was raised, first to 16 and then to 32 spindles. It was the first multiple-filament device that completely finished a yarn from a roving without the use of the spinning wheel.

Richard Arkwright. Richard Arkwright was the most unusual, yet the most modern, man in this entire group. He was not an inventor but a barber by trade, and was an itinerant dealer in human hair, used by

wigmakers. He seems to have been lacking in any degree of technical or general education that might have qualified him for the distinguished place he occupies in economic and mechanical history. England, at that time, was in a ferment of speculation in inventions, and Arkwright had a shrewd native sense for new ideas and an ability to appropriate them when they arose. Capitalists were reaching for new devices and systems of production; while the laborers, beginning to feel the pinch of economic pressure, violently opposed all types of machines to the extent of rioting, of physical punishment in the case of inventors involved, and of smashing machines. There is uncertainty regarding the initial stages and developments of many of the early recognized inventions, a condition which for us further adds to this confusion.

Our modern machine age had its beginning in an obscurity overshadowed by political agitation and change and in vast military and naval operations. This explanation accounts for the lack of adequate literary records.

Arkwright, in going from place to place in his trade of itinerant barber,



Courtesy Chadwick Museum

Fig. 7. The original model of Arkwright's water frame.

heard much of these inventions. He spent much time improving the card and spinning machines, combining the principles of Hargreaves' spinning jenny and Wyatt's rollers, and adding to these the flier from the Brunswick wheel (da Vinci's invention). In 1768, he applied horse power to this composite machine; and in 1769, he applied for and received a patent for the water frame (see Figure 7).

Arkwright seems to have been the first man to conceive the idea of ar-

ranging all of these inventions in serial production, applying the principles of rollers and fliers and cards to the preliminary processes of fiber preparation and spinning, and conducting the operations from the fiber to the finished yarn by machinery, driven by water power.

In 1771, he constructed his first mill at Cromford; but he was not immediately commercially successful. He was a pushing, striving, unscrupulous businessman, and aroused the antagonism and jealousy of his associates, who refused to buy his yarn but did not hesitate to steal his ideas. His systems and machines are notable for the fact that they made it possible to produce, for the first time, an all-cotton fabric in England.

Mention has been made of laws passed in England that protected the silk and woolen industries by prohibiting the importation of Indian cotton printed goods The first law was passed in 1700. As early as 1696, calico printing from carved wooden blocks, and later from etched copper plates, had been introduced into England; and in 1712, in answer to a petition of the woolen and worsted manufacturers, an act prohibiting the use of all printed goods, even those produced in England, was passed. This act was further strengthened in 1721 by imposing a fine of 5 pounds on the wearer and 20 pounds on the vender of printed goods. This action was vigorously opposed by the British manufacturers of calico. They had first printed all-cotton goods sent from India and then made goods with a cotton weft and a linen warp of British manufacture. In 1730, an act of Parliament was passed allowing goods with a linen warp and a cotton weft to be printed but assessing them an excise duty of sixpence per square yard In other words, within less than half a century of the real beginning of the modern cotton industry, Parliament had placed upon even half-cotton printed goods of British origin a nuisance tax.[6]

Arkwright, after the development of his mill in Cromford, had formed a partnership with Jedidiah Strutt, inventor of the derby-rib appliance for stocking rib. Jedidiah Strutt used the first yarns manufactured by Arkwright's mill at Cromford in his stocking-making plant, and furnished the capital and the market to make possible Arkwright's economic life. It is estimated that at least $60,000 in capital was expended in Arkwright's venture before it became successful; but before he could make a commercial success, an appeal had to be made to Parliament to permit the manufacture, printing, and sale of all-cotton goods made in England, with an excise duty of threepence per square yard. In 1774, such a law was passed—the 14th George III, c.72[7]

The date 1774, therefore, marks the real beginning of the modern cotton industry in Great Britain. It marks, as well, the beginning of all modern systems of mass production through serial mechanical operations and the division of labor; and Richard Arkwright was the first titular saint of modern "big business"—the Henry Ford of his age.

Samuel Crompton (1753 to 1827). Samuel Crompton, one of the few inspired mechanical geniuses of this or any age, was a weaver of

---

[6] See Baker, *op cit*

[7] Baine, *op. cit*, p 168 "All of Arkwright's patents were denied by the British Courts in 1785" *Ibid*, p. 192.

respectable character living in the most moderate circumstances in Hall-in-the-Wood, near Bolton. Originally (1440), this had been a beautiful manor house; but in Crompton's time, it had fallen upon evil days and had become a tenement house. Through the generosity of Lord Leverhulme (creator of Lux), "Hall-i'-th'-Wood"—to give it its Lancastrian name—has been turned into a memorial museum to this tragic genius. His machine, the mule, which made possible the spinning of fine cotton threads used in the manufacture of the lighter-weight muslins, is preserved in the British Museum. With obvious modifications and enlargements and improvements, the machine today remains the same as it left the hands of this inventor.

Unlike Arkwright, Crompton was not a businessman; nor does he seem to have had any realization of the economic and commercial significance of his invention. He is supposed to have invented the machine that it might give leisure and competence to labor. It was stolen from him; and his sole reward for the idea that brought untold millions in wealth to England was 5,000 pounds, granted by Parliament, which he subsequently lost in an attempt to improve the methods of bleaching.

Crompton died in 1827, a disillusioned and broken old man. At that time, 6,000,000 spindles, driven by steam, were in operation on the machine he had invented.

Thomas Bell's invention of cylinder printing. In this list of inventors, the Swiss chemist Scheele, who first isolated chlorine for bleaching, is worthy of recognition. But of more importance to the economic evolution of the English cotton business was Thomas Bell's invention of cylinder printing in 1785, in Glasgow. Printing from wooden blocks, borrowed from Asia, had been established in England as early as 1696, and on the Continent in the twelfth and thirteenth centuries. Before Thomas Bell's invention, block printing had been an important and vital craft, requiring long training and great skill. Some indication of what was happening to the labor situation in England may be gathered from the fact that, as soon as Bell's invention was understood and accepted, establishments were founded in which two journeymen had 56 apprentices working for them. In other words the printing of fabrics, like spinning, owing to mechanical invention, could then be performed by women and children—particularly children—as easily as by skilled workmen.

Exploitation of children. The fact has been mentioned that children from workhouses in the different parishes of England were sent to Manchester to live in barracks and to work in the cotton mills, and that every parish was anxious to get rid of its own poor without, perhaps, too much regard to what happened to them in their new environment. There is adequate authority for saying that children as young as 4, 5, and 6 years of age were set to certain of the preliminary tasks in the fabrication of yarns, and in the printing business. They lived in barracks in cotton centers, under conditions too dreadful for description, and worked from 13 to 15 hours a day. As early as 1802, Sir Robert Peel, one of the early successful manufacturers of printed cotton goods, took the matter up before Parliament in an effort to have laws passed protecting apprentices.

> The Act insists that the interior of the mills should be whitewashed twice a year, and that they should be properly ventilated; it enacts that the apprentices shall be provided with proper clothing by their masters: it forbids work for more than twelve hours, and prohibits night work—with a temporary exception for large mills; it provides that the apprentices shall receive elementary education and religious instruction, and lays down rules as to their sleeping accommodation.

This law was almost inoperative and led owners to engage children to work without agreeing on a formal apprenticeship, and there was no adequate inspection or social machinery to enforce it. However, a notable exception to this indifference may be cited. In 1801, Mr. Justice Grose, in a worthy but unusual act, sentenced a man named Jourvaux to 12 months hard labor for ill-treating his apprentices.

In 1816, Sir Robert Peel seems to have thought that the law had beneficial effects at the time it was passed, but it is difficult to believe that the act caused any considerable change in the mills. Even when the parish authorities were moved to interfere, no obvious improvement resulted.[8]

It was not until the reformed Parliament of 1834 that any adequate law was passed protecting labor, even that of children, in English cotton mills. Many of the delusions of today regarding low wages and long hours of employment in the cotton industry may be traced to the survival of traditions of the early nineteenth century; and for this reason, a careful economic analysis of this period is desirable.

Cotton conditions (1790 to 1800). By the last decade of the eighteenth century, cotton preparation and spinning had been reduced to mechanical systems from which few changes separate them from our modern mechanical principles. Cylinder printing had been invented, making possible the continuous process of printing and also the large employment of children and unskilled help at low wages. These machines were driven by water power and later by steam power. Consequently, there was now a surplus of yarn over and above possible consumption by hand-loom weavers; and for a time, the professional weavers were supplied with steady work at high wages. But this condition lasted only for a short time.

The yarn manufacturers exported yarn to the Continent, thus destroying the market for English cloths and establishing great numbers of former agricultural labor as piecework weavers at low rates of earnings. The effect of this colonization of cheap, unskilled labor was later to be duplicated by importing foreign labor into New England and bringing mountain labor to Southern mills in our own generation. The result was almost social chaos. At one time, cotton weavers received only 5 shillings a week, when other mechanical labor earned as high as 20 or 30 shillings.

> It has arisen in this way, that people having very little or no capital, have been induced to begin by the prospects held out to them, perhaps by people in London, and when they have got the goods into the market,

[8] For conditions in child labor during this period see Brown, John, *Memoir of Robert Blincoe;* Cunningham, W. A., *Growth of English Industry and Commerce* (New York: The Macmillan Company); and Toynbee, Arnold, *The Industrial Revolution* (New York: Longmans, Green and Company, 1908).

they have been obliged to sell them for less than they cost, or without regard to the first cost, and this has injured the regular trade more than anything else. I think, . . . when the regular Manufacturer finds that he cannot sell the goods at the price they cost, he is compelled to lower his wages . . . Perhaps three, four or five (of the new persons) may be insolvent every year in the neighbourhood (of Bolton), and when they come to be examined before their Creditors, it turns out the cause of their Insolvency is, the goods being sold for less than they cost. (Mr. Ainsworth's evidence, "Reports, etc., Journeymen Cotton Weavers," 1808, 11, p. 102.) See also the "Report on Manufactures, Commerce, etc.," in 1833. "Trade at present requires industry, economy and skill. During the war, profits were made by plunges, by speculation." "Reports," 1833, vi. 27, printed p. 23.[9]

The age of the power loom. Reverend Edmund Cartwright, in 1785, had patented a power loom, correct in principle but lacking in mechanical perfection.

Long before this time, a Frenchman, a mysterious Monsieur de Gennes, had experimented with the idea of a power loom; and this experiment was described in the *Philosophical Transactions of the Royal Society of England*, in 1687, as "a new engine to make linen cloth without the help of an artificer." It is doubtful, however, if the Reverend Cartwright had seen a draft of this machine, although he may have known of the invention, being a man of scholarly mind and possibly familiar with the *Transactions of the Royal Society*. In Baines' *History of Cotton Manufacture* appears a quotation from these *Transactions:*

> The advantages of this machine are these:—1. That one mill alone will set ten or twelve of these looms at work. 2. The cloth may be made of what breadth you please, or at least much broader than any which has been hitherto made. 3. There will be fewer knots in the cloth, since the threads will not break so fast as in other looms, because the shuttle that breaks the greater part can never touch them. In short, the work will be carried on quicker and at less expense, since, instead of several workmen, which are required in making of very large cloths, one boy will serve to tie the threads of several looms as fast as they break, and to order the quills in the shuttle.

From these observations, the author has acquired a very high respect for Monsieur de Gennes' vision; for today, power looms are in operation where 1 weaver of certain types of cloths, with a single assistant, takes care of 100 looms, with an average pick of 160 per loom per minute.

In 1790, Messrs. Grimshaw, of Gorton, under license from Doctor Cartwright, erected a weaving factory at Knott Mills, Manchester, and attempted to improve on the power loom. This experiment was a costly failure. In 1794, a power loom was invented by Bell, of Glasgow, which was likewise abandoned. In 1796, Mr. Robert Millar, of Glasgow, took out a patent for a machine of this nature, which a spirited individual, Mr. John Monteith, adopted in 1801, fitting up a small mill at Pollokshaws, Glasgow, with several looms. It was several years before this business made a profit.

The original Cartwright loom (1785) was not successful, but a modi-

[9] Cunningham, *op. cit.*, p. 633.

fication of it, perfected by Horrocks in 1803 in connection with a machine for "dressing with starch the warps," invented by Johnston and Radcliffe in 1804, marked the real beginning of power-loom weaving. In hand-loom weaving, no dressing was required for the warps; but in the vigorous action of the early power loom, some treatment of the warps was necessary to permit them to run through the heddles—that is, the devices that opened them into alternate sheds for weaving.

Horrock's loom came into almost immediate general use, but Horrocks himself shared the fate of many inventors—failure and sinking into poverty. But the use of the power loom and the dressing machines spread rapidly through textile England, and, by 1813, there were 2,400 power looms in use and about 100 dressing machines. These machines were the occasion of vigorous machine-breaking riots that sprang up in England during the War of 1812.

R. A. Slaney, Esquire, M.P., stated in the House of Commons on May 13, 1830, that there were in Great Britain 14,150 power looms in 1820 and 55,500 in 1829 By 1833, there were a total of 100,000 power looms in that country.

It is estimated by the same authority that there were 240,000 hand looms in England at the same time. These hands looms were then and later used for the manufacture of fine goods and goods containing woven designs. Hand looms are still in general use in France for the production of style fabrics

Let us examine, for a moment, the influence of these inventions on the importation of cotton:

According to the Board of Trade, England imported 1,976,359 pounds of cotton lint in 1697; by 1764—which date includes the inventions of Kay, Wyatt, Paul, and Hargreaves—3,870,392 pounds of cotton lint were imported. In the meantime, the value of exported cotton goods, or rather goods containing cotton, rose from 5,915 pounds sterling in 1697 to 200,-354 pounds sterling in 1764. (It should be remembered that no "all-cotton" goods were made in England before 1771.)

Baines gives, as an average of importation for cotton lint from 1771 to 1775, 4,764,589 pounds. By 1780, the total had risen to 6,766,613 pounds; and by 1790, to 31,447,605 pounds. Ten years later, in 1800, it had reached 56,010,732. Here begins the great reëxportation of cotton lint from England, for, in this year, 5,406,501 pounds were exported from England.

In 1810, after the power loom had become generally accepted, the import total had risen to 132,486,935 pounds for domestic consumption, and 8,787,109 pounds were being reëxported from England. By 1833, the figures had risen to 303,656,837 pounds in imports, and 17,363,882 pounds in exports.[10]

It is estimated by Baines that, in 1830, 1,000,000 pounds sterling a year was paid in wages to the calico printers The wages varied from 10 shillings to 12 shillings and threepence per week. At this time, it was

[10] For percentages, see Baines' tables.

estimated that the number of hands working in British cotton factories were as follows:

Weaving and Spinning Factories	237,000
Hand-Loom Weaving	250,000
Lacemaking and Embroidery	159,000
Hosiery	33,000
Calico Printing	45,000

—a total of 724,000 people, in addition to which there were bleachers and dyers, calenderers, cutters, sizers, winders, drawboys, and so forth.

The actual value of cotton production in 1930 was somewhere between 24,000,000 and 34,000,000 pounds sterling.

The United States and Cotton

Early history of textiles in the United States. In the early history of the 13 original colonies, there is nothing to indicate the slightest interest in cotton as an economic factor. As a matter of fact, tobacco was of infinitely greater importance; and the British Government, in its anxiety to produce raw material in the colonies for the home manufacturers, encouraged the culture of silk in Virginia with bounties of tobacco. Some small amount of home-grown and reeled silk resulted from this subsidy. There is a tradition, founded on uncertain evidence, that Martha Washington's inaugural dress, which is at present in the Smithsonian Institute in Washington, was made from native Virginia silk and painted in patterns of native wildflowers.

The vast activity in cotton in the eighteenth century in England did not fail to be of interest to the youthful republic of the West. At first, this interest was distributed about equally between the South, the North, and the East. Philosophical societies offered rewards to anyone who could produce machines for the manufacture of yarns.

As early as March 4, in the significant year of 1775, in Chowan County, North Carolina, a Committee of Safety issued this resolution:

> The Committee met at the house of Captain James Sumner, and the gentlemen appointed at a former meeting of directors to promote subscriptions for the encouragement of manufactures, informed the committee that the sum of eighty pounds sterling was subscribed by the inhabitants of this country for that laudable purpose.

In his diary, George Washington mentions a visit made in 1789 to Beverly, Massachusetts, where he saw with great interest a small mill where several cotton threads were spun at a single operation, under the direction of a Mr. Cabot—a name not unfamiliar in later cotton history. This venture seems not to have prospered. More than merely machine designs and drawings were apparently necessary for success. There is perhaps some basis for the legend that a spinning jenny was in operation in Philadelphia before this time.

And in 1790, from Stateburg, North Carolina, an interesting note bore this information:

A gentleman of great mechanical knowledge and instructed in most of the branches of cotton manufacture in Europe, has already fixed, completed and now at work on the high hills of the Santee, near Stateburg, and which go by water, ginning, carding and slubbing machines, with eighty-four spindles each, and several other useful implements, for manufacturing every necessary article in cotton

Samuel Slater. In 1790, there landed in America an English textile mechanic, Samuel Slater, trained in the school of Arkwright and imbued with the success of that unusual man. He started operations in the old

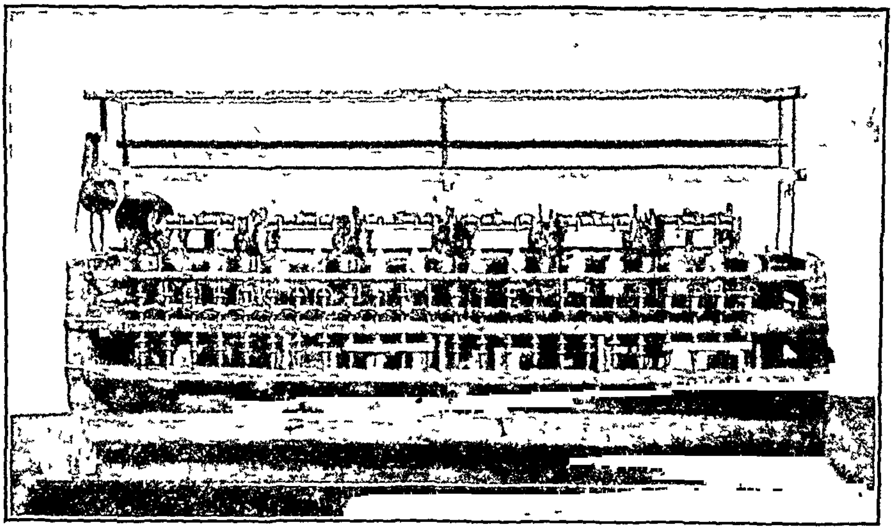


Fig 8 The old Samuel Slater spinning frame, originally operated in Pawtucket, Rhode Island, 1790

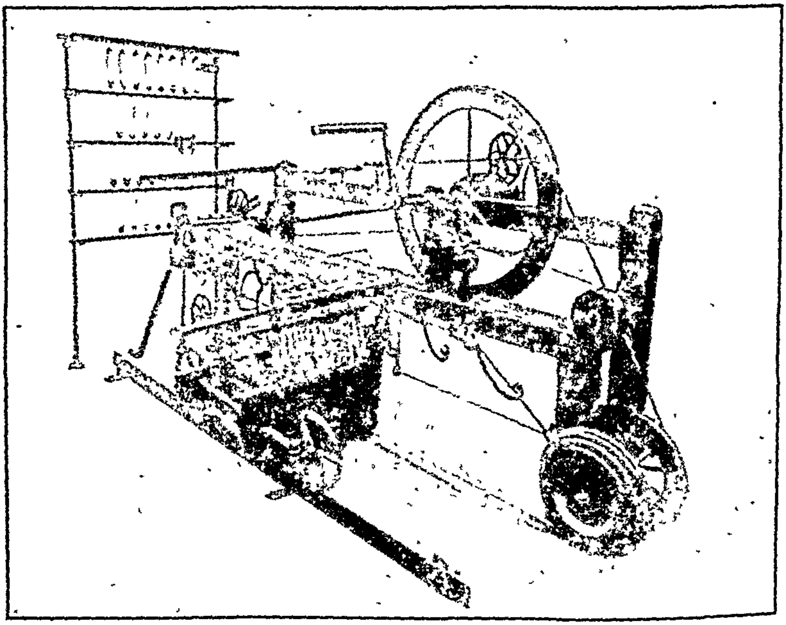
fulling mill of Ezekiel Carpenter's clothing shop, on the east bank of the Blackstone River, on the southeast abutment of Pawtucket Bridge. His equipment consisted of 3 cards and 2 spinning frames built entirely from memory. One of these cards and one of the spinning frames, containing 48 spindles, are now in the National Museum in Washington (see Figure 8).

The entire business was carried on by Samuel Slater and 9 assistants, nearly all of them young children. Early in 1793, Slater, with 2 partners, Obadiah Brown and William Almy, built a new factory, especially designed for the cotton business. This mill had 3 cards, 2 spinning frames, and a total of 72 spindles, and was set in operation on July 12, 1793. This was the first English-type cotton-spinning mill on the American continent and followed the Arkwright system. The old Slater mill still stands in Pawtucket. It has been turned into an interesting type of *textile museum; that is, it is a museum without any exhibits as yet, but* with great hopes for the future

In 1798, Mr. Slater formed a partnership with his father-in-law, Oziel Wilkinson, and with William Wilkinson and Timothy Greene, and to-

gether they founded the firm of Samuel Slater and Company. Slater was superintendent of both mills and received from each mill $1.50 a day for his services, or $3.00 a day from both mills. He was a hard-working man, and he claims to have labored 16 hours a day for 20 years.

John Slater, a brother of Samuel Slater, arrived from England in 1803, bringing with him a knowledge of Crompton's spinning mule (see Figure 9). In 1805, a new enterprise was planned, Almy, Brown, and the two



Courtesy Chadwick Museum

Fig. 9. Spinning mule invented by Samuel Crompton, 1779.

Slaters each taking a fourth interest; and, during 1806, the erection of a mill was begun in the northern part of Rhode Island, on the south branch of the Blackstone River. This was the beginning of Slatersville. John Slater eventually bought out all the other partners, and the mills and village were passed on to his grandson, John W. Slater.

> In 1811, in company with a young man named Bela Tiffany, who had been in his employ a number of years, Samuel Slater started a cotton factory at Oxford, Massachusetts, and part of which village is now known as Webster, about 35 miles northwest from Providence, Rhode Island. An excellent water power was furnished by the French River and several ponds. At first, the business was conducted under the name of Slater & Tiffany, but it soon came wholly into the possession of Samuel Slater, and ultimately was carried on in the name of Samuel Slater & Sons. The property in 1817 consisted of one cotton factory of 2,000 spindles, a wooden mill, a grist and saw mill, 16 dwelling houses, and 700 acres of land.
>
> In 1822 with Willard Sayles and Lyman Tiffany of Boston, Oliver Dean of Franklin, and Pitcher & Gay of Pawtucket, Slater formed a company, and purchased an estate consisting of a small cotton mill,

several tenements, and a fine water-privilege at Amoskeag Falls, on the Merrimack River. This was the foundation of the well-known Amoskeag Manufacturing Co., and the real beginning of the great manufacturing city of Manchester, New Hampshire.

The War of 1812, by shutting out foreign goods, gave a great impetus to domestic manufacture, and as Samuel Slater had all his various enterprises well under way, he was enabled to reap great advantage. Cotton cloth sold at 40 cents a yard, and the demand was unlimited. Besides the interests which he possessed in the mills already mentioned, he invested capital in woolen and iron manufacture, and other lines of business.

According to a memorial presented to the United States Congress, there were reported to be at the close of the year 1815, 99 cotton mills in Rhode Island, with 75,678 spindles; in Massachusetts, 57 mills, with 45,650 spindles; and in Connecticut, 14 mills with 12,886 spindles; making a total of 170 mills operating 134,214 spindles. The average capacity of cotton mills at that time was only 500 spindles. The 'Old Slater Mill' at Pawtucket up to this time the largest in the country, contained 5,170 spindles.[11]

It only remains to add one paragraph to the history of the famous Slater mill:

> Where they run for about twenty months, and overstock the domestic goods market, several thousand pounds of yarn having accumulated in that time, notwithstanding the most active exertion on the part of the proprietors to dispose of the product, both in yarn and in cloth, woven by hand .

So at this early period of our industry we already were enjoying the vicarious satisfactions of the condition known as "overproduction," the result of making a product for an assumed market and of not planning in advance how to dispose of it.

Up to a few years ago, in Slatersville, Rhode Island, the original building of 1806 still stood. Even today, one of the buildings built in 1826 is used as a warehouse and is a part of the Slatersville Finishing Plant, owned by the H. P. Kendall Company.

First power loom and warp-dressing machine. In 1811, Francis C. Lowell, of Boston, on a visit to Edinburgh, became very much interested in the power-loom industry of that city and determined to visit Manchester, England, to see if it were possible for him to obtain any information on this subject. The delicacy and the difficulty of Mr. Lowell's position will be appreciated by the knowledge that, at the time, it was a criminal offense to export from England either models of machinery, parts of machinery, or working drawings of machinery. However, he seems to have overcome these difficulties and such pricks of conscience as may have disturbed him. He returned to Boston in 1813 and, with the assistance of a Patrick T. Jackson and Nathan Appleton, purchased a water-power site in Waltham, Massachusetts, obtained an act of incorporation, and began the manufacture of cotton goods by power looms in America.

[11] Lewton, Frederick L., *Samuel Slater and the Oldest Cotton Machinery in America,* Smithsonian Report for 1926.

The mill was capitalized at $400,000; just how much of the capital was paid in is difficult to determine at this late date. That so large a capital was authorized indicates the hope of financial profit rather than of industrial expectation. But one loom, at least, was in operation in the autumn of 1814. Mr. Lowell's loom differed in certain respects from the English loom. Like much later American machinery, the problem of skilled labor was important, and the machines had to be adjusted to the limited environmental technology. The dressing of the warp was also a difficult matter; and in the pamphlet describing this interesting process, Nathan Appleton seems to have confused Horrocks, inventor of the power loom, with Johnson and Radcliffe, inventors of the dressing machine. At any rate, this confusion of mind did not prevent Mr. Lowell from getting a drawing of this vital English machine and producing a satisfactory duplicate.

First domestic cloth—demand and construction. At the time the Waltham Company first began to produce cloth, there was but one place in Boston where domestic cloth was sold. This was a shop in Cornhill, kept by Isaac Bowers, or rather by Mrs. Bowers. As but one loom was operating, the quantity accumulating was not very great. However, there was great difficulty in selling even this limited production. Mrs. Bowers was quoted as having said that everybody praised the goods and made no objection to the price, but still she made no sales. A parcel of these goods was next sent to the store of B. C. Ward and Company.

The construction of this cloth may be of interest. It contained 44 warp ends and 44 weft picks to the square inch. The yarn was Number 14—that is, 1 pound contained 14 hanks of 840 yards each, and each yard weighed approximately one third of a pound. That this type of cloth was well suited to public demand was a matter of accident, and it was sold unbleached. The finer cotton goods in this country at this time were supplied from India, a by-product of our packet-ship trade in tea and spices with the Orient. The first considerable sale of the domestic goods was made at auction at over 30 cents a yard. B. C. Ward and Company were appointed permanent selling agents, and they charged 1 per cent commission for selling. The commission form of selling began at this time.

The tariff of 1816. In 1816, a new tariff was made. The Rhode Island manufacturers were clamorous for a very high specific duty. This feeling was largely due to the fact that they did not as yet have the power loom. Mr. Lowell was at Washington for a considerable time during the session of Congress. His view on the tariff was much more moderate than that of Rhode Island manufacturers; and he finally brought Mr. Lowndes and Mr. Calhoun to support the minimum of 6¼ cents per square yard, which rate was adopted.

Competition from abroad. During the same year, there was a crisis in the cotton business of Rhode Island, owing to the flooding of our markets with English cottons. For the first time, our home weavers felt the full impact of fabrics woven on power looms in England. The only spindles that were running were a few in the old Slater Mill, and these

were making yarn for hand looms. Profits in the War of 1812 had been so great that manufacturers had been satisfied with their equipment, and no improvements had been made in machinery. Mr. Lowell assured them that the introduction of the power loom would put a new face upon manufacture and enable them to meet English competition. He next proceeded to Providence and returned by way of Taunton, where a vertical power loom was discovered, which did not seem to promise much success.

Mr. Lowell is given credit for being the first American manufacturer who entirely processed cotton, from lint to cloth, under one roof.

Labor in early cotton mills. The first labor in the cotton mills came from the farms of New England and from those portions of the female population whose husbands and fathers were engaged in marine ventures of one kind or another. The introduction of machine spinning and carding had made home manufacturing unprofitable and had thus created a surplus of female labor.

In Nathan Appleton's pamphlet, *The Introduction of the Power Loom, and the Origin of Lowell*, 1858, mention is made of boarding houses established by the company, "under the charge of respectable women, with every provision for religious worship and care of the morals of the workers." Lowell and others had been strongly impressed by the shameful conditions in England, but attributed them, not to their true economic causes, but to the lack of morals among the workers. They attempted to protect American workers from moral dangers incident upon machine production without much interest in the underlying evils of low wages and long hours.

This pamphlet contains, among other interesting matter, a scale of prices for the fabrics mentioned:

Year	*Cents Per Yard*
1816	30
1819	21
1826	13
1829	8½
1843	6½

Power. Textile production, up to the end of the eighteenth century, was almost entirely a matter of hand and foot power. The introduction of fulling mills and dye plants began the use of water power with overshot and undershot water wheels, and perhaps wind mills, in Italy, Flanders, and England as early as the thirteenth century. The next step was water power, applied in the eighteenth century to the spinning and carding machines of England. The partial abandonment of water power in favor of the Watt steam engine, and the modern phase, beginning with Fourneyron's invention of the turbine in 1832, have now led to the power plants, distributing electric power from a central location to the modernly equipped mills, where each machine has its individual motor.[12]

[12] Usher, *op. cit.*, Ch. XXVIII.

Botanical features of United States cotton. Certain botanical features of our cottons have had a direct influence on mechanical development and the early geographical distribution of the cotton industry in the United States.

The cotton plant was not native to our present cotton states, except in those areas more recently developed in the Southwest. It is supposed to have been introduced by the Spaniards in their (then) province of Georgia early in the sixteenth century. Little attention was paid to the type of seeds planted; and since cotton is very sensitive to cross-pollenization, this lack of botanical knowledge resulted in a hybrid type of cotton.

Our cotton type developed a characteristic which must have excluded us from world cotton commerce, except for an American invention of unusual merit—the Whitney cotton gin.

The ancient cottons of India, those of Brazil and the islands of the Caribbean Sea, and the modern cottons of Egypt have a smooth seed, to which the lint is but lightly attached. In India, a simple device of two smooth wooden rollers, known as the "Churka," is sufficient gently to separate the lint from the seed. The Churka is as much a part of Gandhi's mechanical equipment as the spinning wheel. This machine has today a logical evolution in the roller gins used in all fine cotton ginning.

The bulk of our cotton crop in the eighteenth century, as today, botanically belonged in the group of hairy seeded cotton (*genus hirsutus*), in which the lint clings too firmly to the seed to be separated by the gentle action of rollers. Cotton was grown for domestic uses only on our colonial plantations after the Revolution, and there is some record that, at one time, its cultivation spread as far north as southern Pennsylvania But it was only used in hand crafts upon the plantations, since the seeds had to be extracted by hand; and even with slave labor, this was a comparatively expensive operation.

Cotton from the 13 colonies was of no apparent interest to England, because her greatest demand did not arise until after the events leading up to the Revolution were well under way and because of the character of the seeds.

It is estimated that, as late as 1791 (when England was already far advanced in the production of cotton yarns and fabrics by mechanical means—even after the beginning of the application of steam to cotton machinery was well under way and the first mechanical spinning mill had been founded in Rhode Island—the United States produced 2,000,000 pounds of lint, of which only 200,000 pounds went to England. The remainder seems to have been used for domestic purposes, spun on the Brunswick spinning wheel and woven on hand looms. It was an easy matter to raise the cotton plant in the fields of the South; but at that time, it could not be deseeded at a cost to compete with the raw cottons from the West Indies, Brazil, and India, which England was then buying in increasing quantities. The Southern planters were by no means indifferent to this situation and looked with interest on England's growing demand for cotton. They recognized its importance as a money crop equal to or greater than indigo or tobacco.

Invention of the cotton gin—Eli Whitney. At about this time, Eli Whitney, a graduate of Yale, with perhaps as good an engineering training as the times and location provided, and evidently of a mechanical bent, accepted a position as manager of a large estate in Georgia owned by Mrs. Nathaniel Green, widow of the brilliant Revolutionary general. Whitney heard the planters of the South discuss the possibilities of the cotton trade and the difficulties in regard to the American hairy-seeded cotton. In 1793, he perfected the cotton gin (see Figure 10) which still

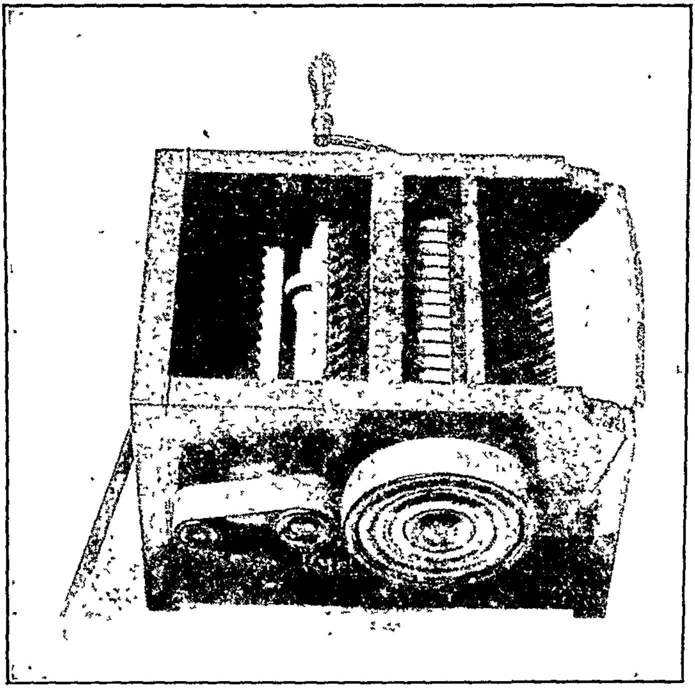


Fig. 10. Eli Whitney's cotton gin, invented in 1793

bears his name and whose principle is employed in over 30,000 cotton gins, scattered throughout the cotton states of the United States and the world. Whitney cotton gins prepare over 98 per cent of our crop for market.

His brilliant idea consisted of a box in which the cotton boll, containing the seeds was placed. Through the floor of this receptacle were metal-covered slits, through which circular saws revolved. These slits were too narrow to admit of the passage of the seeds, but the lint was stripped from the seeds and eventually cleaned off the teeth of the saw with a revolving brush.

The invention was stolen from Whitney in the first week of its existence, and he never received any financial benefit from it. Subsequently, he became a rich man from the profits of a venture in the manufacture of firearms, to which he applied the principle of division of labor and

mechanical processes—proving not alone his technical versatility but also that he had a clear comprehension of the economic principles involved in the evolution of machinery.

Marked increase in cotton consumption and exports. In 1793, the year the cotton gin was perfected, 487,000 pounds of cotton were sent to England, a large proportion of it from South Carolina; in 1794, 1,601,700 pounds; in 1795, 6,276,300 pounds; in 1796,[13] 3,788,429 pounds; in 1798, 9,360,005; and in 1800, 17,789,800.

A decade later, in 1811, on the eve of the war with England, 62,186,081 pounds were exported from the Southern plantations to English ports.

In the next two generations, domestic consumption of cotton advanced on a very sharp curve. Just before the Civil War, in 1860, there were 5,235,727 spindles in operation in the United States; and in 1870, 7,132-415. These were mostly in New England. Estimated in terms of cotton bales of 500 pounds each, the domestic consumption of cotton lint was as follows:

Year	*Bales*	*Pounds*
1850	240,000	120,000,000
1860	918,926	459,463,000
1870	905,243	452,621,500

In the year 1859–1860, England's consumption of cotton in bales of approximately 500 pounds was as follows:

Country	*Bales of 500 Pounds*
United States	2,522,000
Brazil	103,000
West Indies	10,000
East Indies	563,000
Egypt	110,000

Effect of the Civil War on exports. The above statistics were no doubt in the mind of Senator Hammond of South Carolina when he declared, in the Senate Chamber at Washington, in 1858, that the North would not dare go to war with the South. His words are as follows:

> Would any sane nation make war on cotton? Without firing a gun, without drawing a sword, should they make war on us, we could bring the whole world to our feet . . . What would happen if no cotton were furnished for three years?

The honorable Senator lacked an economic imagination and was not familiar with the history of the long wars that England had waged with her wool customers in Europe.

During the Civil War, the Northern blockade practically shut England off from American cotton; and her imports from world markets were as follows:

---

[13] The drop was due to war with France and troubles in Ireland.

Country	*Bales of 500 Pounds*	*Loss or Gain in Bales*
United States	198,000	2,324,000 loss
Brazil	212,000	109,000 gain
West Indies	60,000	50,000 gain
East Indies	1,798,000	1,235,000 gain
Egypt	319,000	209,000 gain

In other words, during the 4 years of our Civil War, England ringed the world with cotton plantations. How much this change in the source of supply of cotton cost England and England's customers may be vaguely estimated by the following statistics:

In 1859–1860, the average price of cotton ranged between 10¾ and 11⅜ cents a pound. By 1865, just before Lee's surrender, the price had risen to $1.82 a pound; and, on rumors of peace, it fell to 43 cents a pound. In these calculations it must be remembered, however, that there was a serious inflation of currency in the United States.

Manufacturing in New England. To return to the development of manufacturing in New England After the successful development of Slater's Mills, in Rhode Island, and Lowell's weaving mill, in Waltham, Massachusetts, there followed a generation of mill incorporations inspired by our expanding frontiers and our Oriental trade. In November, 1824, the Massachusetts Legislature set off a portion of Chelmsford as a separate township; this township was incorporated in 1826 as the city of Lowell, and a company was formed to manufacture cotton goods and to control water power The Great Falls Manufacturing Company was organized in 1823; Amoskeag Manufacturing Company, in 1831; Laconia Mills in Biddeford, Maine, in 1845; Pepperill Manufacturing Company, in 1850; and Pacific Mills in Lawrence, Massachusetts, in 1854. These mills were mostly engaged in the manufacture of the coarser types of cotton goods—merchandise that was desirable for a rapidly expanding agricultural country and for the trade that the packets, and later the clipper ships, of New England enjoyed in the markets of the Orient

Cylinder printing with power machines had been introduced by the middle of the nineteenth century, as had the manufacture of coarser ginghams and a certain amount of bleaching, dyeing, and finishing.

First steam-operated cotton mills at Salem. At this time, the ancient seaport of Salem, Massachusetts, once famous for her witches and packet ships, began to see her ocean trade diminish in favor of Boston and New York Hence, shrewd merchants and sea captains organized the Naumkeag Steam Cotton Mills, the first mills in the United States to be operated by steam. While these mills were built in 1839, they did not begin to operate until 1847. They were rebuilt after the Salem fire of 1908 and are still in existence, manufacturing Pequot sheets and pillow cases.

New Bedford—its rapid rise as a cotton manufacturing center. In 1847, the prosperous city of New Bedford, Massachusetts, on Buzzards Bay, gave no indication that a time would come when the whaling industry would diminish in profits. There were at this time 500 ships that

cleared from Buzzards Bay. But since whalers were of the masculine persuasion and since every ship had an average crew of between 20 and 30 members, these conditions resulted in a large surplus population of available female labor; also, since there was adequate capital in the town and the whalers were, in many cases, traders as well as whalers, the opportunity for the manufacture of cotton goods could not be resisted. Therefore, the Wamsutta Mill was organized in 1847.

Since the manufacture of staple and coarser goods had already been preëmpted by the older established New England companies, it was decided to make finer goods in New Bedford and to build up a new market for such products. It is rather curious, in the light of later events, that the man who first conceived the idea of a cotton mill in New Bedford should have been an employee of a cotton mill in the South, owned by Dwight Perry, a resident of Fairhaven. Thomas Bennet, however, was a former resident of New Bedford, and he was ambitious to run a mill of his own. He appealed to Joseph Grinnell, a member of Congress and a well-to-do citizen of New Bedford. Mr. Grinnell, at first strongly inclined to locate the mill in the South, was easily persuaded—if rather against his will—to make the venture in his native city With the aid of David Whitman, a mill engineer of Rhode Island, the mill was finally put into operation in 1849, with 15,000 spindles and 200 looms. The capital investment was about $160,000.

The venture was a success from the start. It is estimated that, at that time, there were 10,000 men engaged in the whaling industry; and this fact meant a great number of women available for mill labor. In 1854, two additional mills were erected, bringing the total spindlage up to 45,000, with an adequate complement of looms. In 1907, the corporation was capitalized at over $3,000,000, had 228,000 spindles and 4,300 looms, and employed 2,100 operators.

Conditions favored establishment of cotton mills. During the Civil War, the Southern privateers, having been driven from the Atlantic Ocean by the Union Navy, conducted raids in the Arctic Ocean and destroyed a large number of whalers. It is interesting evidence of the ingenuity of the old whaling captains that, from then on, in an effort to protect themselves from these depredations, they painted portholes on the sides of their sturdy vessels to imitate warships. There followed a series of tragic disasters on the icy seas and the beginning of competition with mineral oil; these facts changed local sentiment and diverted capital to the development of cotton mills. Twenty-four additional cotton mills, manufacturing cloth and yarn, were established between 1847 and 1906.

Other mills were later added so that, by 1920, there were in New Bedford 3,500,000 fine yarn spindles and 50,000 looms. It was the center of the fine-yarn cotton industry in America, using combed yarns and intricate machinery; and there were no mills in all the world better equipped or manned than those of New Bedford.

Conditions detrimental to the prosperity of the cotton industry. There was no adequate supply of water near New Bedford suitable for bleaching or finishing. The goods were sold in the gray to converters

and later to jobbers, and even to certain types of garment manufacturers; by these second hands, they were sent to bleachers, finishers, dyers, and printers to be processed for the market. As fine-yarn spinning and weaving grew up in Connecticut, Rhode Island, in the South, and in Maine, the same dangerous merchandising practice was followed. The Wamsutta had, in addition to other looms, a group of looms manufacturing fine bedding, and these were the only New Bedford products that were then known either to the public or to the markets as a New Bedford product. During the First World War, New Bedford manufacturers, instead of firmly establishing their product in the markets of the United States and the world, left bare of fine goods formerly received from northern France, devoted their manufacturing to the production of automobile-tire yarns. The end of the war found that the tire manufacturers were using entirely different types of yarn and cotton for tires and that the market had developed other sources of supply for fine cotton goods New Bedford's prosperity started in decline from the Armistice, until, by 1932, it was running not more than 25 per cent of capacity and mill stocks that paid high dividends for years had fallen to about one tenth of their former prices.

Just before the First World War, two fine-yarn mills were built and equipped in Greenville, South Carolina, and a large number of fine-combed yarn-spinning mills grew up in Gastonia, North Carolina. A few years later, the then so-called "Insull group" in the Central Maine Power Company entered the fine-yarn-goods field; and the Berkshire group, scattered through Massachusetts, Rhode Island, and Connecticut, was another unit to enter.

There were other scattered units, all of them selling unfinished goods none controlling the quality or style of their product to the market, and none with any market identity. Most of these units later came under banking control, and consolidation, elimination, and liquidation were the order of the day.

Labor

At first, labor was entirely local in type, absorbing the surplus labor, largely female, from agriculture and maritime pursuits. Employers and employees were of one race and language, and, generally speaking, of one religious inclination. Such social distinctions as existed were entirely concerned with degrees of wealth and education.

Early in the nineteenth century, foreign immigration began to play a part in mill labor. First came the vigorous Irish, in answer to the pressure of economic conditions. Then followed a wave of well-trained British weavers and even a few Scottish mechanics, forced from the old country by industrial saturation. Next came the thrifty French Canadians, seeking to save money from mill wages to buy and stock their pleasant farms in Quebec provinces. These fine industrial workers were separated not only from the Yankees, but from the British, the Scotch, and the Irish workmen, by the barrier of language; and from all except

the Irish, by a religious difference. But, as a matter of fact, there was a difference even here, since, in practically all New England communities, separate French Catholic churches were established; and ever since, the French have maintained what, for social purposes, amounts to a distinct religious organization of their own race.

The Irish, English, and Scotch mixed easily with the native population, but the French held aloof. Socially, they belonged to another century; economically, they were farmers, temporarily diverted to mechanical pursuits in order to accumulate working capital for their agricultural investments; and they clung tenaciously to their own beautiful language and sturdy customs, and maintained a social solidarity, even in matters affecting their religion. In addition, they had a strong recollection of the tragic revolt of the French *l'habitants* against the English rule in Quebec in the early part of the nineteenth century (1837)—the revolt of Louis Joseph Papineaw.

New Bedford and the near-by town of Fall River were subject to the same general racial influences as other New England towns, but in one particular they differed. The New Bedford whalers, at a very early date, had come in contact with the vigorous nautical population of the Cape Verde Islands. Crews of whaling vessels were seldom subject to inspection by immigration officials, and, as whaling became unprofitable, it became a custom to bring back cargoes of workers from the Cape Verde Islands for the New Bedford mills. These islands were known to the Carthaginian voyagers before the Christian era. They were rediscovered in 1441 by the Genoese merchants, and later became Portuguese possessions. Racial mixture was already sufficiently complicated in the islands before they became ports of call for the slave trade from Africa, even before the discovery of the New World. Today, out of a population of 140,000, less than 5 per cent are of supposed unmixed white descent. The rest are either mulattoes or full-blooded Negroes. They are excellent workmen, frugal, industrious, and, when treated fairly, docile. The racial distinctions, so important in this country, do not exist in these islands, and the Negro Portuguese are just as intelligent and just as skillful workmen as their white compatriots.

The introduction of the Portuguese into New England marks the end of voluntary immigration. During the early nineties, in an effort to obtain cheap labor in competition with the South and to avoid the threat of organized labor that had been raised by the growth of the Knights of Labor—and under the economic delusion that low wages meant low costs of production—there began a wave of vicious labor proselyting in southern Europe, Asia Minor, and Asiatic Russia. The racial confusion resulting from this misguided effort may be judged by the fact that, in 1912, at a famous labor trial in Lawrence, Massachusetts, 19 different languages or dialects were translated in the testimony.

There can be little doubt that this sudden intrusion of alien labor, misdirected and exploited, created a very difficult social and economic problem in New England. Labor solidarity was impossible. There

were the barriers of languages, social standards of living, and religion to be considered.

A strong distinction grew up between management and labor. The remnants of the older races, by this time comfortably domiciled in New England, occupied positions of minor executive responsibility. The later immigrants became the workers, while ownership rested largely in the earlier American families who brought the industry first into economic life.

With the restrictions of immigration, the day has passed when our labor standards can ruthlessly be determined by comparison with the living standards of the latest labor importations from Europe. Our school systems, general habits of life, and the ability to obtain citizenship are gradually assimilating all of these races and setting the second generation in the commonly accepted social and economic mold. The slow rise of living standards and education and the gradual correction of the worst effects of this racial experiment clearly indicate that the almost discarded idea of the melting pot need not yet be entirely abandoned. At least, from this southern European labor group, New England is relearning the frugal habits of our own earlier generations. They brought with them from their European homes a knowledge of subsistence agriculture; and the truck gardens and small farms of New England play an important part in augmenting the family income. There does not seem to be any prospect of again throwing down the bars of immigration and permitting a new era of labor exploitation. The more enlightened mill owners and operators are not in favor of such a course.

Cotton Mills in the South

The rapidly developing demand for cotton, first in the mills of England and later in those of New England, following the invention of the Whitney cotton gin, prevented or discouraged the development of cotton-textile mills in the South, in favor of agricultural development. But the impetus that had been given to the original idea of imitating England's machine development carried the South up to as late as 1810. At that period, the manufactured products of the Carolinas and Virginia exceeded the value of the manufactured products of New England, and a certain amount of cotton spinning and weaving was carried on in the South for local sale up to the Civil War.

But the modern history of Southern cotton mills does not begin until after the Civil War. I quote from Broadus Mitchell's *The Rise of Cotton Mills in the South:*

> The mills built after the War [Civil War] were not the result of pre-bellum mills. This is trying to ascribe one cause for a condition which probably had many causes. The industrial awakening in the South was a natural reaction from the War and Reconstruction. Before the War there was first the domestic industry proper. Then came such small mills about Winston-Salem as Cedar Falls and Franklinsville. These little mills were themselves, however, hardly more than domestic manufacturers. When, after the War, competition came from the

North, and from the larger southern mills, the little mills which had operated before and had survived the War lost their advantage, which consisted in their possession of the local field. . . . The ante-bellum domestic factory system did not produce the post-bellum mills.

The following statistics taken from the *Census Reports* are illuminating:

TABLE I

Area	*Census*	*Plants*	*Capital*	*Operators*	*Spindles*	*Consumption in Bales*
Southern States	1840	248	4,331,078	6,642	180,927	
	1850	166	7,256,056	10,043		78,140
New England .	1840	674	34,931,399	46,834	1,497,394	
	1850	564	53,832,430	61,893		430,603

After the Civil War, or rather after the even more destructive and misnamed period of reconstruction, had passed away, a few of the leading citizens of the South, with the idea in mind of giving employment to the unemployed and almost unemployable white population that had been detached from the soil through slavery, launched what really amounted to a cotton crusade. This incident marks one of the most interesting and one of the most human stories in the history of the industry. But even before this, in 1861, there had been an exhibition of machinery in Atlanta intended to encourage the manufacture as well as the growing of cotton in this section and to induce foreign capital to invest in these ventures. The war, of course, interrupted this idea.[14]

The Charleston Manufacturing Company, in its first bid for stock subscriptions, printed the following message:

> The advantages, direct and incidental, accruing to every citizen of Charleston from this industry about to be started in our city, are so manifest that those who have inaugurated the enterprise have every reason to feel confident of a ready response to the call for capital and of abundant success.

The personal losses incident upon these first experiments are an indication of the unselfishness and the public-spiritedness, as well as the inexperience, of Southern industrialists. There is no doubt, however, that the machinery manufacturers in the East encouraged the movement and took stock in some of these Southern mills, often to the extent of from 40 per cent to 60 per cent of the indebtedness; but they no doubt charged a compensatory price for their machinery.

It was not until 1895 that the Southern mills passed safely through the first stages of sectional enthusiasm and social devotion into a clearer and more rational economic position. The East and the North first watched this movement with a tolerant and amused indifference. Well-established mill organizations in the East, trading in a rapidly expand-

[14] See *United States Census Reports*, 1831 to 1910.

ing market, with a skillful and docile labor population and strong financial and mechanical and scientific background, did not seriously consider the competition of the South.

Textile Machinery[15]

American versus English machines. It is impossible to outline the subsequent history of mill building in the South without some brief reference to the difference between American and English machine technology. The English machines, as a whole, were invented for a labor population that had been trained for generations in textile processes and was partially organized in industrial groups and systems at least 100 years before the invention of the first machine. From the very beginning, the English machines were found to be too complicated and to require too great an amount of skill for the available labor in the American markets.

The early phases of the cotton industry in the United States were devoted exclusively to the production of the coarser types of cloth; and these, in most instances, were unfinished. An attempt was even made to transfer the machines or the machine ideas to the home. One of these machines, fortunately preserved in the Smithsonian Institute, combines a gin, roller draw frame, and 6 spindles, and was intended to be driven by hand power. This machine was manufactured in Cincinnati as late as 1844. It is curious as representing a composite labor-saving machine intended for the home rather than for the factory.

The mule. The mule was introduced in America by John Slater, brother of Samuel Slater, in the early nineteenth century. The extension of the use of this machine was limited by the lack of technically trained spinners; and most of the spinning in this country before 1832 was performed on modifications of the Slater machine, based on the earlier Arkwright patent.

John Thorpe's invention. In 1828, John Thorpe patented a machine (see Figure 11) for twisting, with a metal cup device that is still used in worsted spinning; in 1829, he perfected ring spinning. This device consists of a large and heavy metal ring to which is attached a smaller ring, through which the partially spun filament of cotton is passed on its way to the spindles. Both of these rings are lifted by the weight of the thread itself; and the action of friction, coupled with the rapid revolution of the spindle, completes the finished yarn. The peculiarity of this spindle was that it had to be driven at a high rate of speed—between 8,000 and 9,000 revolutions per minute—and the weight and size of the ring and the size of the roving determined the size of the yarn. This condition made necessary certain changes in the type and character of the spindle; and the Rabbeth high-speed spindle, perfected in the great Draper plant in con-

[15] For lack of space, many inventions vital to the development of the cotton industry or common to other fibers have been omitted. For a full account of the technical evolution of modern machinery, see William S. Murphy's *The Textile Industries* (London, 1911), in 8 volumes.

nection with Thorpe's ring—in which the spindle shaft is wrapped in worsted yarn—made it possible, after many experiments with oil-bearing jackets were abandoned, to drive these machines at this high rate of speed. The worsted yarn controls vibration in the rapidly revolving spindles. Here is a example of a simple addition to an original idea having all the force of an invention.

Ring spinning now prevails in over 90 per cent of the American cotton industry and, within the last 30 years, has been introduced into England, South America, Japan, and the Orient. It not only can be operated by much less skillful operators but makes a stronger yarn, though it lacks the certain character of softness in the mule-spun yarn. Ring spinning has a second advantage of the utmost importance in modern manufacturing: it is a continuous movement, whereas the mule is an intermittent movement. The mule only forms the yarn while the carriage is traveling outward; when the carriage moves backward toward the spindle, it is wrapping yarn on the spindles. The ring frame also occupies much less space in a mill, and an operator can take care of a greater number of spindles; hence there is a greater production per spindle.

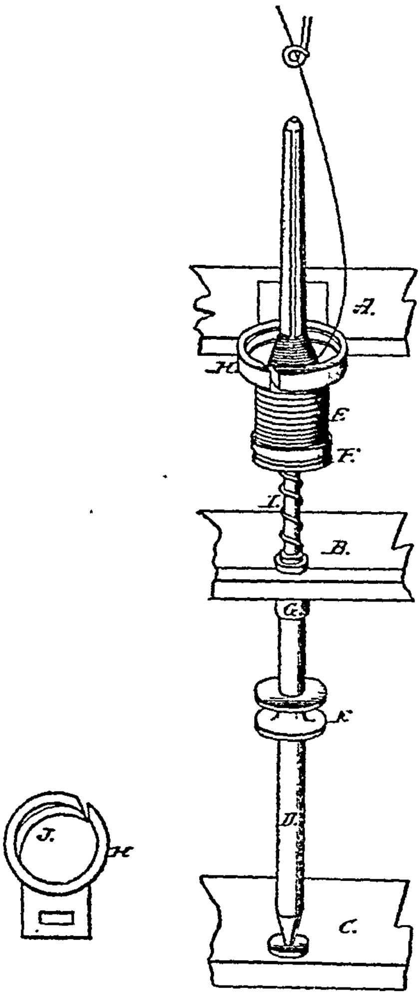


FIG. 11. Machine for spinning and twisting, patented by John Thorpe in 1828.

Dutcher temple. One of the difficulties experienced in the early use of the power loom was the absence of a device to keep the cloth stretched to correct width after it had been woven. On hand looms, this difficulty was taken care of by two wooden sticks, clamped together with nails, that were fastened to the cloth and, from time to time, shifted as the cloth was rolled on the cloth drum. To use this implement on the power loom, where weaving was at so much greater speed, not only made it necessary to stop the loom from time to time and hence to create loss of production, but made it impossible for a weaver to take care of more than two power looms at one time. The Dutcher temple (also a Draper invention), a de-

vice resembling a perforated metal drum, was introduced at this time; and the irregularities on this metal surface constantly revolving, with the picking motion of the loom, kept the cloth to its proper width. A weaver with the same effort could now care for from four to eight looms.

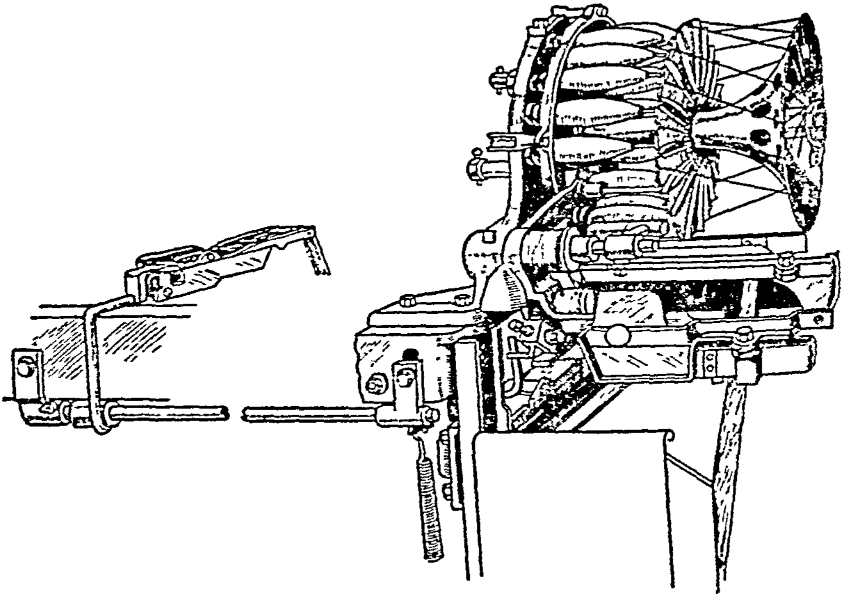
Continual improvement in the power loom during the nineteenth century. The technical history of the loom is an intricate yet important subject to students of mechanical development. But it is enough for our purpose to say that, during the first half-century that followed the introduction of the power loom, slight changes were always being made in methods of construction and mechanical details, which made the movements more regular and prevented an undue amount of the breakage of yarn due to strain on the warps. These modifications in the United States were all in the direction of greater production, with less and less need for specially trained labor. But the main change was that the loom gradually contained more and more metal, and less and less wood. From 1835 to 1894, the plain-cloth loom reached a standardization of mechanical detail that has been only slightly modified since. Its main objection was that 1 weaver could take care of from only 4 to 8 looms, and the main loss of time was due to the breaking of warps and the necessity of inserting fresh bobbins in the shuttle as the weft was used up in weaving.

Two devices were perfected to correct the first fault, one a mechanical stop motion on a loom and the other an electric stop motion, which causes the loom to cease weaving without damage to the fabric if a single warp end breaks.

Northrop battery loom. We now come to the invention that has had a greater influence on the so-called problems of mass production and overproduction in textiles than any other single invention since Arkwright's water frame. In 1894, the Draper Company, with the assistance of a talented, if somewhat temperamental, English mechanic, J. H. Northrop, invented what is known today as the Draper, or Northrop, battery loom. This loom (see Figure 12) has an attachment at one side containing a battery of bobbins, which, through a simple but amazing piece of mechanism, throws out the empty bobbin from the shuttle and inserts a fresh bobbin, without stopping the motion of the loom—performing these actions in the twentieth of a second, the period of time in which the shuttle rests in the shuttle box.

It is an amazing comment on the lack of technical imagination in the cotton industry to write that the introduction of this loom in cotton mills was one of the most difficult of commercial-mechanical undertakings. Fall River, at this time, was a thoroughly established center for the manufacture of print cloths. Cotton mills had been established in Fall River since 1811; and, by the early nineties, Fall River had grown to be one of the richest industrial cities of its size in the world, with a population of between 20,000 and 25,000 workmen employed in spinning, weaving, bleaching, and printing plants. The Draper Company attempted to introduce their new loom, but the mill owners of Fall River could see no reason why they should scrap machinery that was still in good working

order and on which they were making a profit. Mechanical obsolescence was then an unknown phrase. This forced the Draper Company to seek a market for their looms in other parts of the world and in the South.



Courtesy Draper Exhibits

Fig. 12. Details of connection of Northrop loom.

The Northrop loom is one of the most perfect mechanical implements ever devised to perform a series of intricate, yet restricted, mechanical movements. Its operation does not require any very high degree of skill or any length of technical training. It can be operated successfully by women as well as men.

England refused at first to see any particular advantage in the Draper machine. Even as late as 1930, English labor unions refused to let a weaver tend more than 12 looms when he could take care of twice or three times that number even on fine fabric. The consequence was that the machine was introduced first in the South, later in South America, and ultimately in the Orient. The Draper Company was supported in their development of Southern mill properties and foreign mills by the manufacturers of spinning machinery, particularly Soco-Lowell, ring-frame makers. The growth of the industry in the South and its present relative position, compared with those of the East, are a part of the mechanical history of Thorpe's ring, Dutcher's temple, the electrical and mechanical stop motion on the loom, and the Draper or Northrop loom. When, in 1931. Gandhi was visiting the great weaving center of Manchester, England. he remarked on the fact that, in physical equipment, the English mills were far below the mills that had been built within the last generation in Bombay, India.

Crompton-Knowles looms. This modern machine was developed, in the latter part of the nineteenth century, from the earlier Kay drop box (1760) and the Knowles rod-and-ball chain shuttle box, combined with the William Crompton chain-motion shedding device. This fortunate combination of constructive inventive genius has developed into the great Crompton and Knowles Loom Works, in Worcester, Massachusetts. To these earlier principles many new devices and adaptations and perfections have been added, until these looms have gone into every phase of the textile industry and into many parts of the world. Their 2-by-1 box-shuttle change is one of the most amazingly rapid and precise bits of mechanism in the history of machinery. Crompton and Knowles Loom Works make looms, not only for silks and cottons and worsteds, but for carpets and rugs, and for many other specialized purposes. Their relationship to the fancy woven industry is as important as that of the Draper Company of Hopedale, Massachusetts, to the high-speed production of plain cloths.

The Vaucauson and Jacquard patents. In the old Oriental looms, the weaver often embroidered with a shuttle on bare warps the most beautiful and intricate patterns. An old Chinese loom shows a device that corresponds closely to the loom used today in intricate patterns, known as the "Jacquard." It must be remembered that all devices, machines, and inventions in Europe were only intended to make automatic movements and constructions formerly produced by hand—craftsmanship. The loom used today to make such fabrics as brocades is miscalled the Jacquard loom. The beginning of this type of loom mechanism is to be attributed to the Vaucauson patent, in 1746, and not to Jean Jacques Marie Jacquard, who perfected the Vaucauson devices. Vaucauson's patent consisted of cords, with weights attached to warp, in association with sheets of perforated metal not unlike the device now used on our player pianos. The cords were attached to groups of warps and controlled the pattern through the weights dropping through the holes in the metal sheets. This device led to Jacquard's more practical machine and is the prototype of all modern looms of this character.

Knitting machinery. We must include in this group the knitting machinery that began before the era of orthodox dates for the economic revolution. The Reverend William Lee completed his stocking-knitting frame during 1589. John Heathcoat, in 1808, constructed a machine capable of producing pillow lace; John Levers, in 1813, improved the Heathcoat machines and invented a lacemaking loom; and M. I. Brunel, in 1816, patented his circular knitting machine, which was known as the "Tricoteur."

Weaving color into fabric. On hand looms, when a pattern called for an additional color in the weft, the weaver changed to a shuttle already prepared with a bobbin of the desired color. This change hardly interrupted his labor.

The first invention to make this movement automatic was Robert Kay's drop box, patented in 1760. This device contained two shuttles with different colored bobbins, which, by mechanism, were offered in

turn to the pick block. This device and the earlier fly shuttle of John Kay, 1733, are still used on hand looms.

Most fancy fabrics—such as ginghams, stripes, and the smaller patterns—are today made in the United States on the Crompton-Knowles loom.

Hand craftsmanship still of primary importance. The completion of these inventions has given the modern mill operator a very wide control over pattern, color, design, and texture in fabrics. If you add to this list of inventions the looms that make pile fabrics, modern technology includes practically every principle formerly known and developed through hand craftsmanship in any part of the world. But this control and mechanical duplication of movements and technics developed in hand craftsmanship do not imply that hand craftsmanship has disappeared or ceases to be of primary importance. As a matter of fact, the finest of all fabrics are still produced on crafts implements and under craft systems and control, and these influences have increased rather than diminished during the last few years. No thoughtful student of textile history should make the mistake of eliminating such factors from careful consideration. The hand loom is an economic, artistic, and commercial factor of the first importance.

10

The Modern Textile Industry

Five Phases of Turmoil

The second revolution. The background of the textile industry, as portrayed in the preceding chapter, explains much about the kaleidoscopic trends of the modern textile industry, which will be outlined in this chapter.

The antiquity of spinning and weaving, owing to the fundamental human need for clothing, made this branch of manufacture the forerunner of modern industry, the pivotal point of the first industrial revolution. And this position of leadership created, in turn, an intrenched position of tradition that made textiles the branch to be first and most sharply affected by what may be called the "second industrial revolution"—and particularly that part of it which developed in the two decades immediately following the First World War.

This second industrial revolution, confined almost entirely to the present century, has found major expression in these phases: (1) the creation of entirely new industries; (2) the geographical dislocation of industry; (3) the technological advance in existing industries; (4) the projection of new social-economic trends; and (5) the increasing complexity of the merchandising problem.

The initial effect of most of these new impulses upon the textile industry has been a negative one. The potential effect is positive. During the transition period, however, many old companies in an old industry fall by the wayside. That fact earned for textile manufacture, in the 1920's particularly, the characterization of "a sick industry." The later emergence of that industry to a forward-looking status has been one of the most inspiring chapters in modern industrial history.

To understand the net import of this complex situation, it is necessary to appraise each of these trends in its effect upon textile manufacture. The effort is particularly worth while because textile manufacture affords the best case study of a long-established, overcompetitive, consumer-goods type of industry. Much of the publicity during the last quarter-century has been focused upon the new industries, such as automobiles, radio, synthetics, air-conditioning, and so on; upon allegedly monopolistic, rather than actually profitless, industries; and upon capital-goods

industries—or upon varying combinations of these three descriptions. The plight of an industry which falls into no one of these grooves has been made that much more difficult because there has been the assumption that what was good or necessary for the most publicized types was good for all.

Creation of new industries. There is a temptation to consider this particular phase of the subject in its broader sense and to study the effect of new branches of manufacture, outside of the textile industry, upon that industry. This would include such varying and often opposed factors as the demand for textiles from the new industries and encroachment of the latter upon the consumer's dollar, to the detriment of textiles. However, there is a much more specialized industrial growth to consider in this connection, namely, the development of synthetic fibers.

The romance of rayon ranks especially high in modern industrial history, from the standpoint of human interest. To textile manufacturers, it has been both a problem and an opportunity of the first magnitude. Here is the background:

In 1911, the first "artificial silk" plant was established in this country, producing something over 1,000,000 pounds in 1912. By the end of that decade, the consumption of this new fiber in this country had reached less than 10,000,000 pounds. By the end of the next decade (1930), however, the total was approximately 127,000,000 pounds, while at the end of the next decade (1940), the total domestic consumption was nearly 500,000,000 pounds. In other words, it increased by more than 50 times in just two decades.

The transformation in the characteristics of the product of the new industry was equally remarkable. From the first shiny, weak "artificial silk" used mostly for knitted neckties and sweaters, there has been developed a bewildering range of filament yarns and staple fibers varying widely in source, in appearance, and in use.

The first effect upon textile manufacture was a stimulating one. The sharp increase in output of "artificial silk" in the early 1920's permitted the creation of low-priced novelty fabrics of cotton and rayon mixed, replacing the old staple ginghams and similar fabrics, and serving as a real temptation to a woman's pocketbook. As time went on, however, many of the existing types of mills lost out, owing to changes created by the growth of the new fiber. Naturally, it replaced a certain amount of cotton yarn, which affected both spinners and mercerizers Its most ruthless effect, however, was felt in the old silk mills. Their machinery, organization, and managerial outlook were difficult to adjust to the demands of the new industry, and many of these organizations—including firm names that were household words in this country—passed out of existence. Their place was usurped by cotton mills that processed rayon, and by newly created rayon-weaving mills.

A similar possibility confronts the woolen and worsted industry. Just as the early filament rayon replaced silk more and more in weaving plants, so the comparatively new rayon staple threatens to replace wool more and more in both men's and women's wear and in household and

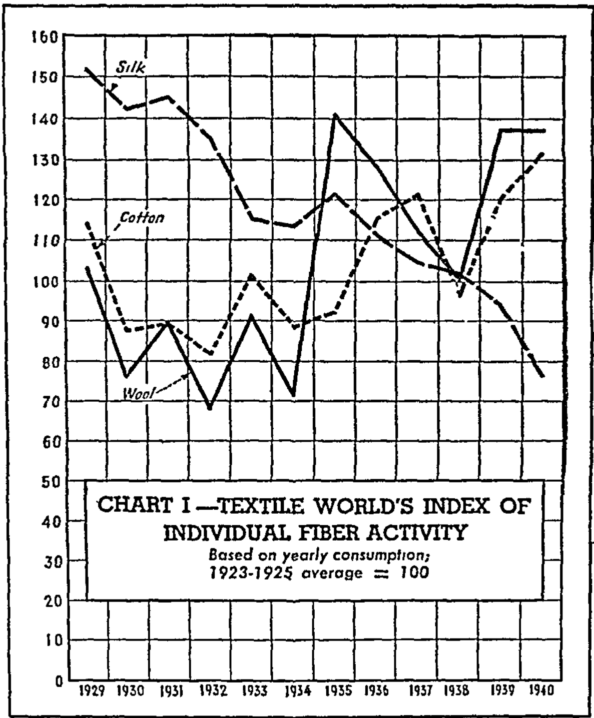


CHART I—TEXTILE WORLD'S INDEX OF INDIVIDUAL FIBER ACTIVITY
Based on yearly consumption; 1923-1925 average = 100
Silk
Cotton
Wool
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940

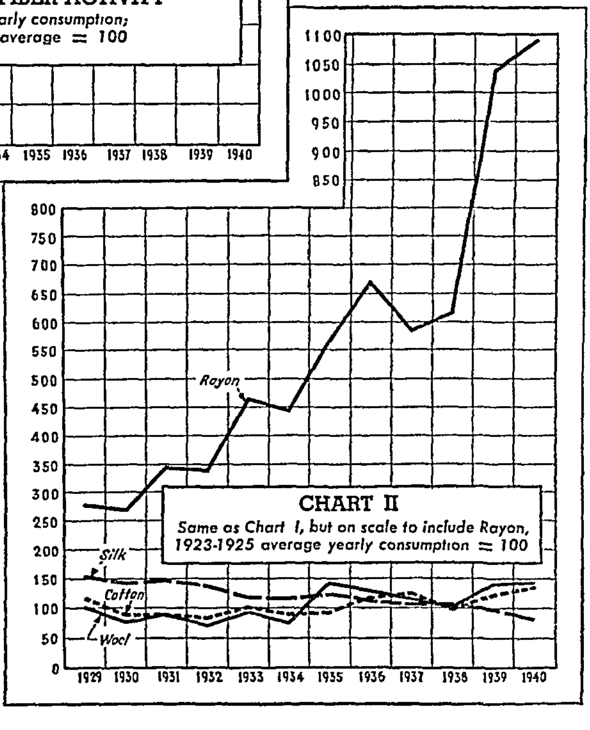


CHART II
Same as Chart I, but on scale to include Rayon, 1923-1925 average yearly consumption = 100
Rayon
Silk
Cotton
Wool
1100 1050 1000 950 900 850 800 750 700 650 600 550 500 450 400 350 300 250 200 150 100 50 0
1929 1930 1931 1932 1933 1934 1935 1936 1937 1938 1939 1940

industrial fabrics. The wool manufacturer of 1940 found himself facing the same possibilities which the silk manufacturer faced back in 1922.

The above refers principally to the weaving branch of the industry. Although most of the earliest inroads of synthetic fibers upon the textile industry were directed toward knitted products, the later development centered on woven materials; and, in fact, one of the major branches of knitting—full-fashioned hosiery—continued as a last stronghold for silk until as recently as 1940. In that year, entirely new types of synthetics appeared—by now well known to consumers under the names of Nylon, Vinyon, and others—and threatened to replace silk even in that last field. Silk still comprises the raw material in the largest part of the full-fashioned hosiery industry, but the production of Nylon and other new synthetics is increasing rapidly, and the handwriting seems to be on the wall.

Two characteristics have been responsible for this spectacular growth of synthetics, namely, uniformity and versatility. The former has resulted in the elimination of many other great natural industries, as, for example, natural dyes. Man, with the help of the chemist and the engineer, can regulate his plant to produce practically the identical product week after week, while nature seems unable to achieve this uniformity. In versatility, man can adapt the characteristics of synthetic products exactly to the uses required of them

The net result has been a complete revolution in the material sources of textile manufacture in this country.

New England Follows England's Pattern

Geographical dislocation of the industry. Just as it was true that the creation of new materials within the textile industry was only a part of the broader picture of the creation of new industries generally, so also is it true that the much-discussed shift of the cotton manufacturing industry from the North to the South was essentially only part of a national and, in fact, a world decentralization of industry generally. Probably the most spectacular example on the world's stage was the rapid decline in the extent to which England supplied far-flung markets Gradually, countries to whom she had formerly shipped goods began to create their own industries and thus to supply their own needs, while other industrially aroused nations also stepped in to take away a part of England's erstwhile markets.

Exactly the same impulse was manifested in this country. The earlier picture of New England supplying a considerable part of the industrial needs of the United States changed to one where the other sections became industrially conscious.

Here, again, the textile example was the sharpest of all such dislocations.. This was due, partly to the fact that a basic industry such as textile manufacture is always one of the first to interest a country newly awakened to its industrial possibilities, and partly to the fact that there was at least a psychological tie-up between cotton manufacture and

the growing of the raw material, which represented such a considerable proportion of the South's agricultural economy.

The result can be told in a very few figures. Within the two decades from 1920 to 1940, the relative position of the New England states and of the cotton-growing states, with regard to the number of cotton spindles, was completely reversed. At the start of that period, New England had well over half the spindles; while at its conclusion, the South had approximately three quarters of the total. The comparison on the basis of actual consumption of cotton in the two sections is even more striking, since, in 1940, the South was consuming about 85 per cent of the total used by domestic mills.

There was not only a shift in the percentage between the two sections but also a very sharp drop in the total number of spindles for the country as a whole. In the 15 years between 1925 and 1940, there was a reduction from a total of about 38,000,000 to approximately 25,000,000 spindles. As indicated above, the bulk of this represented a loss to New England. The result is familiar to anyone who has traveled in that section in recent years: huge mills, and often almost entire cities, stripped of their major occupation—cotton-textile manufacture. Practically all the production of staple goods was shifted to the South; those plants that remained in New England were largely producers of fine goods and novelties.

It is possible to analyze only briefly the cause for this shift. The major one, in this writer's opinion, is the national and world trend already mentioned In other words, although it was true that certain conditions following the First World War hastened the shift, it is probable that eventually the cotton-textile industry would have been decentralized anyway.

The major specific factors that made up the cost differential in attracting cotton-textile mills from the North to the South were wages, taxes, and construction costs Of these, by far the most important was the wage factor. A considerable part of the North was unionized, and the wage scale had assumed a certain amount of rigidity; while in the South, there was a vast supply of labor from the mountains waiting to be tapped. The tax differential was due partly to the eagerness of Southern communities to entice plants to their midst, and their consequent willingness to offer attractive arrangements whereby taxes were waived for a certain period.

The total differential in cost, which was a very considerable factor at the height of the migration from New England to the South in the 1920's, was gradually reduced in subsequent years, particularly in the comparison of the Piedmont section of the South with New England. Costs in the Charlotte, North Carolina, area, for example, have steadily increased; and today such sections as Charlotte, which have become increasingly industrial, find history repeating itself in a new form of competition which they face from the more rural areas of Georgia, Mississippi, Alabama, and other Southern states.

The net effect of such a geographical dislocation is not hard to realize.

An industry already facing overproduction problems, through addition of another shift during the emergency of the First World War and its aftermath, experienced the impact of new plants whose product came on the market during the worst of this competitive situation. For that reason, the cotton-textile industry staged a private depression all its own long before American industry in general took to its bed in 1930.

We have referred specifically to the cotton-textile industry because this was the one most sharply affected. Subsequently, the hosiery industry has had a similar migration, although not yet as sharp in its total manifestation. The big question of the future is whether woolen and worsted manufacture is going to follow cotton manufacture. There has been some migration of wool manufacturing plants, from the North to the South, and some establishment of entirely new plants. However, the woolen and worsted industry is still largely a Northern enterprise. It is interesting to note, for the benefit of those who have a primary concern about the wool division of textiles, that this branch faces two dilemmas: (1) the threat of rayon staple; and (2) the threat of geographical dislocation. In other words, it may well be proved that the wool industry's troubles are still ahead of it, while the cotton industry has laid many of its troubles to rest.

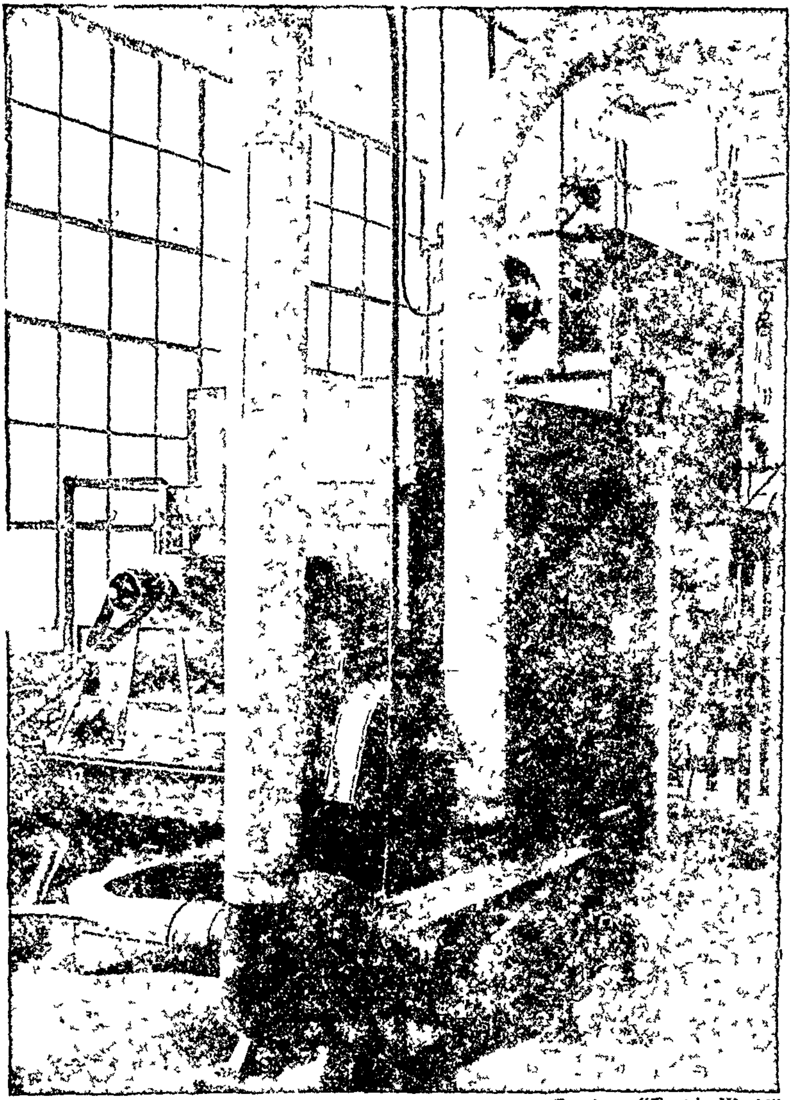
Old Processes Under Attack

Technological advance. The wave of technological development that has characterized American industry thus far in this century has naturally not ignored the textile industry. Unfortunately, its effect to date has been depressing rather than bullish. In many industries, it served either to reduce costs so sharply as to increase total consumption and consequent total profits or to result in the creation of entirely new products and new industries which enable old companies to compete against the shelf.

In textile manufacture, the initial effect was largely to increase overproduction, bear down on price and wage levels, and create a less profitable economy for both management and labor.

Even the scrapping of a part of the equipment of certain divisions of the industry did not restore a production-demand balance. The reason was this very same technological advance. For example, cotton spindles in the country declined, in the decade from 1930 to 1940, from about 34,000,000 to 25,000,000. On the other hand, the production of cotton goods in yards increased from about 7,000,000,000 to 9,000,000,000. Through the improvement of machines, and particularly through the improvement in management methods, as well as further extension of the second shift, each unit of equipment in place was capable of producing a larger unit of product.

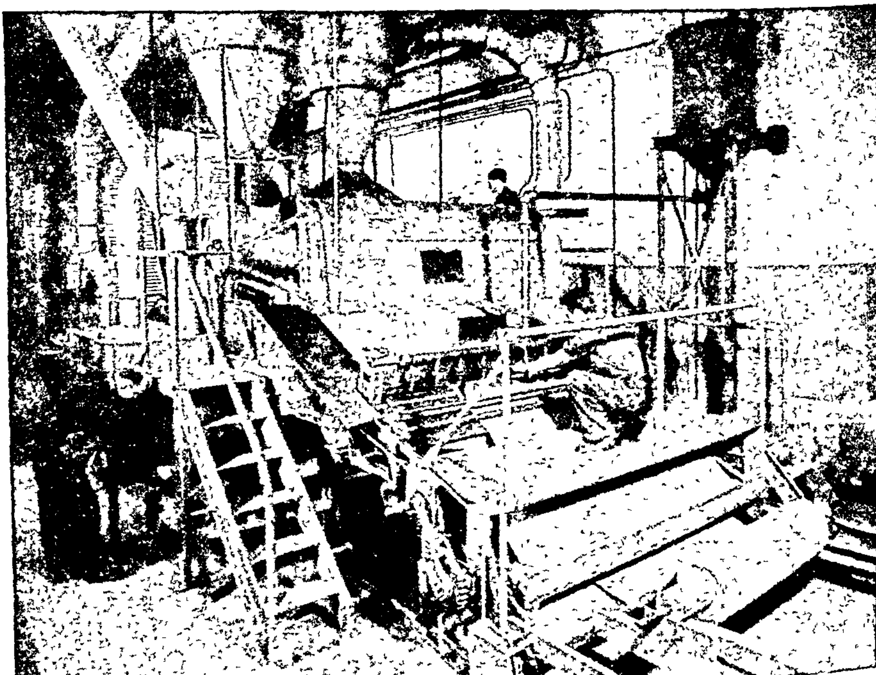
Although it is safe to assume that certain of the trends toward increased productivity of existing equipment have more or less run their course, there is no prospect of technological stabilization in the textile industry. The trend of the next quarter-century will undoubtedly be



Courtesy, "Textile World"

Fig 1. Stock-dyed wool roving from cards ordinarily used in production of face yarns for carpets is fed to a Taylor-Stiles fiber cutter, chopped into predetermined lengths ranging from 5/32 in to ½ in, then blown into this mixing machine The mixer consists of a large chamber with fans and a revolving wire cage which acts as an agitator and thoroughly mixes the flock Jute, rayon, and other materials can also be used

toward complete transformation of existing processes. There are tendencies pointing that way already. Fabrics have been created without benefit of spinning frame or loom.[1] The effect upon this industry, if it should be found possible to by-pass such standard forms of its equipment, would be revolutionary in the extreme. This will not happen overnight, but there is enough of a possibility in this direction to challenge the imagination of the textile industry and those who supply its equipment.



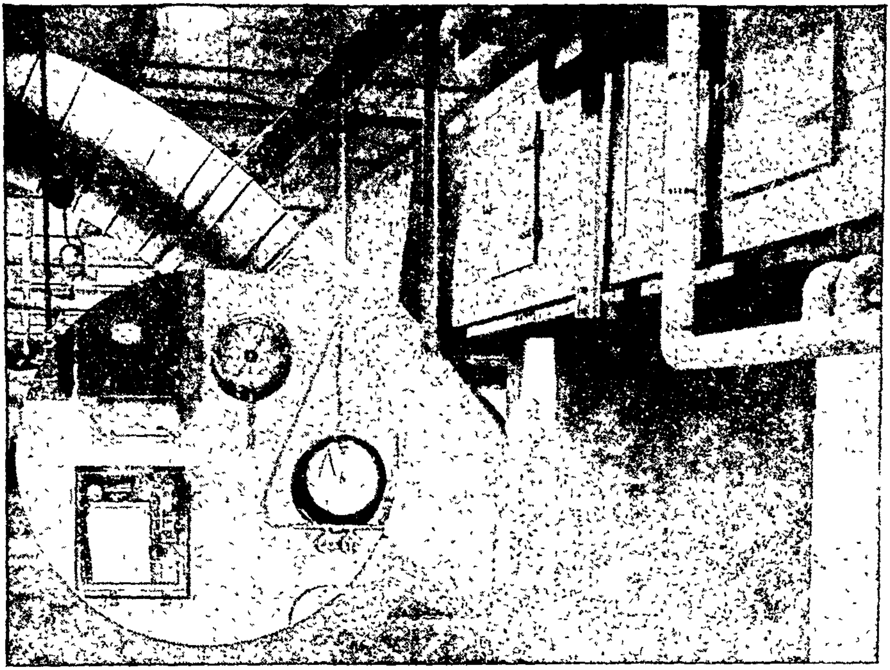
Courtesy, "Textile World"

Fig. 2 Here actual production of carpet begins. The roll of burlap shown at right, with one side rubber coated to a thickness of up to 0.045 in, is drawn into the machine rubber side down, and the series of nozzles in front of the stooping operative gives the uncoated burlap face a coating of naphtha rubber cement The burlap then enters the flocking chamber (center). Flock, which has been blown from the mixer to a bin, is spread in controlled amounts across the width of the machine, then allowed to sift down to the cement-coated burlap through openings. A suction device next draws up and returns to the bin all flock which has not become lodged in cement. The "raw" carpet is then drawn out of the chamber and carried up a lattice conveyor to a dryer.

New social-economic trends. The effect of technological improvement upon both corporate profits and wages was referred to in the preceding section. Possibly in no other branch of industry are the economic

[1] The process, as pictured in Figures 1, 2, 3, 4, and 5, outlines briefly the making of the carpet shown in Figure 6 This is an example of the elimination of looms and spindles by the use of a method with interesting potentialities.

and social factors so closely related as in textiles. The reason is simple: The wage item, being such a large part of the total cost in textiles, represents the main competitive battleground. In other words, when overproduction is having its bearish effect, price-cutting sets in; and the only way this can be continued is through wage-cutting. At the depths of the depression, particularly in the year 1932, the effect of this upon existing wage scales was shocking. The worst feature of all was that the industry



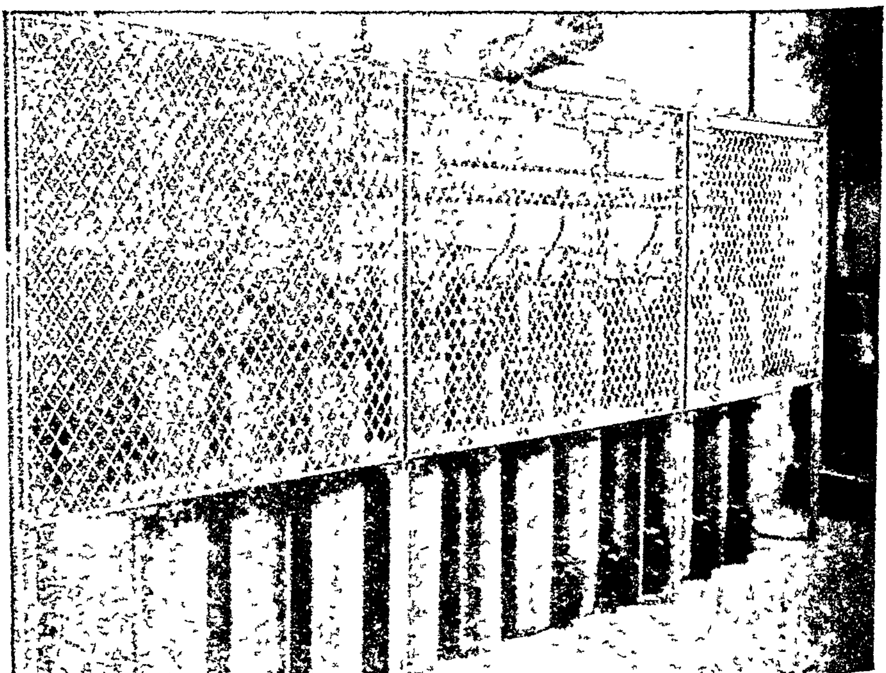
Courtesy, "Textile World"

Fig. 3. This is the 125 ft. long dryer through which the carpeting passes The dryer is divided into two sections, the first maintained at about 310° F., the second at about 260° F Three circulating fans control flow of warm air through dryer. Approximately 22 min is required for the carpet to travel from one end of the dryer to the other. During drying, the rubber backing expands to over ¼ in. in thickness and becomes cushion-like and springy; also the flock becomes firmly cemented in place Inset shows dryer controls. In case of emergency the entire machine can be stopped by pressing a single button.

was apparently powerless to stop it. Made up of numberless small units, and prevented by law from acting in concert, there was nothing that one manufacturer could do but follow the lead of his possibly more ruthless competitors. All the premium supposed to be inherent in good equipment and good management vanished before the collapse due to price and wage-chiseling.

It was for that reason that the textile industry took the greatest interest in the development of the NRA; in fact, it became the first guinea pig.

since the cotton-textile code was NRA Code Number 1. Even in advance of the act, the industry, through the Cotton-Textile Institute, voluntarily restricted its weekly hour scale by reducing it to 55 hours for day workers and 50 hours for the night shift, and by eliminating the night employment of women and minors. This was followed by the still more radical step of setting a maximum of a 40-hour week, just before the NRA went into effect. In fact, this action was probably responsible more than any other for the coming of the 40-hour week to industry.



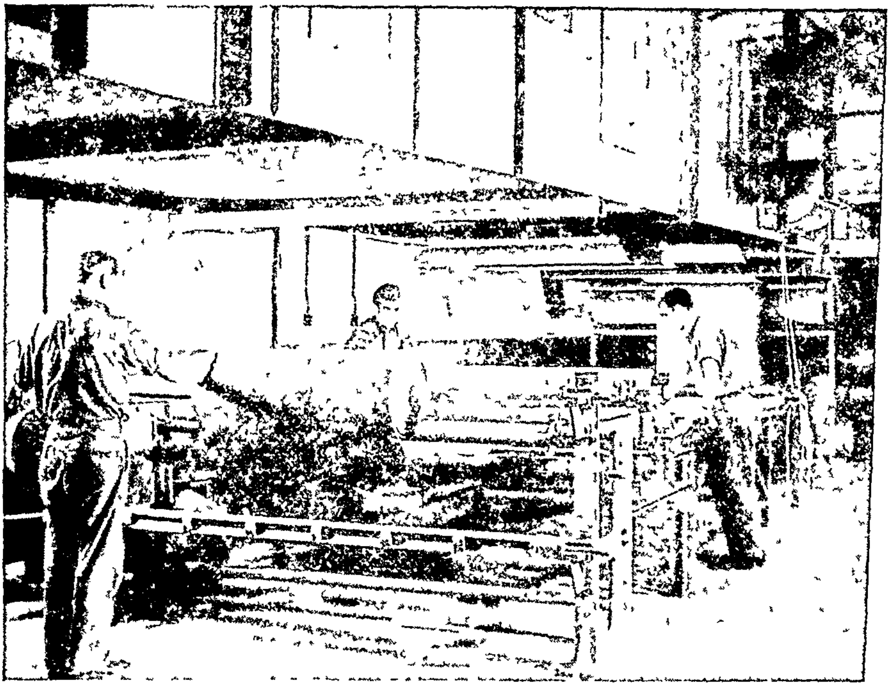
Courtesy, "Textile World"

Fig 1 Protection against fire at any point in the dryer is afforded by this equipment Eleven cylinders containing fire extinguishing chemicals under pressure are connected to the dryer at various points and controlled in such a manner that in case of fire chemicals feed into every part of the dryer.

Despite the discouraging experiences in certain phases of the administration of the NRA codes, far-seeing men in the industry realized that some such ceiling over hours and floor under wages represented the only answer to a decentralized and overcompetitive industry. Furthermore, since it was neither practical nor legal for the industry to act on its own and to force noncoöperators in line, it was apparent that some sort of Government aid and supervision was necessary. The latest experience in this direction has been under the Federal Fair Labor Standards Act, popularly known as the "Wage-Hour Law." The industry's scale of minimum wages and of actual wages is now at the highest in its history.

Merchandising problem. Obviously, the main problem facing the textile industry is to develop new products, to reduce the cost of existing products, and to compete more effectively for its share of the consumer dollar.

This requires a positive—not a negative—attitude, since many other industries are encroaching upon the textile domain. Paper products have made serious inroads into many of the household uses for textiles This is just one example Textiles must not only hold their own, but must



Courtesy, "Textile World"

Fig 5 After drying, cloth is cooled brushed, lightly steamed and oil sprayed, inspected, trimmed along edges, and wound on rolls The machine can handle carpeting up to 81 in in width, top production speed is approximately 10 ft per min To make rugs, carpeting can be sealed with latex

develop ways of going ahead At the moment, this is the subject of a major promotional drive under the auspices of groups identified with the cotton-textile industry. Other divisions of the industry have a similar problem still to face

Tied in with this promotional need is the need for technical research. This has been recognized by the Textile Foundation and the United States Institute for Textile Research, which have made considerable progress in this field during the last decade and have just announced a working arrangement pointing toward a more effective program.

The industry-wide efforts require also individual jobs in merchandising on the part of the various companies.

Conclusion. It will be noted from the above that the textile industry has suffered grief enough in the last two decades. The encouraging lesson to be drawn from this brief analysis is that those companies that have weathered the storm and are still doing business, as well as the new com-

Courtesy, "Textile World"

Fig. 6. Finished carpet created without benefit of spinning frame or loom.

panies that have come into existence, face—and know that they face—a situation in which there is no Santa Claus. Their present policies and their present determination represent, in this writer's opinion, an excellent guide for those who want to study what happens to an industry after it goes on the rocks. The textile industry is emerging from a depression of nearly two decades. It gives promise of being one of the leaders of American industry in technological development, social awareness, research, and merchandising aggressiveness.

11

The Cotton-Growing Industry

The Cotton Crop of the United States

Cotton is one of the leading crops in the United States today, when considered from a money-yielding standpoint. The value of the farms on which cotton is produced, including all personal property and improvements, is about $9,000,000,000. In monetary value, it leads all crops except corn.

Cotton is the main crop of the South. Each year prior to 1934, from 40,000,000 to 46,000,000 acres were planted with it, and the yield ran from 10,000,000 to 18,000,000 bales of 500 pounds each. In 1940, the acreage was about 25,000,000, yielding a total production of about 12,000,000 bales of cotton There are 17 states where cotton is grown. The cotton-growing industry is located in these states because of the favorable climatic conditions and the relative abundance of comparatively cheap labor. There are more than 6,000,000 individuals employed in the production of this staple, and more than 10,000,000 people are living on farms that produce some cotton. There are over 500,000 people employed in manufacturing cotton goods, the value of which exceeds $1,500,000,000 annually.

Factors in Determining the Value of Cotton Staple

The value of cotton is determined, first, by grade and, second, by length. The term *grade* includes the color and the amount of foreign matter, such as small particles of leaves and stems mixed with the lint The length of staple as a rule varies from ¾ of an inch to more than 2 inches. Other things being equal, the value of staple is determined by the length. While the price of cotton is based on grade and staple length, other factors—such as fineness of fiber and strength of the raw cotton—are receiving increased attention on the part of manufacturers. Strength is especially important, since, in a large measure, it determines the use to which the cotton can be put. Recent researches of the United States Department of Agriculture and other agencies have revealed that variety of cotton and conditions under which a crop is grown influence fineness, strength, and spinning value. The wall of the cotton fiber is

made of chains of crystalline cellulose, which are laid down at an angle to the longitudinal axis of the fiber. All cotton has the same general structure, but the angle of the cellulose chains to the axis on the fiber varies with variety and growth conditions; and the angle, in turn, is related to strength, the smaller the angle the stronger being the cotton. Varieties with small angles and greater strength are being selected for uses where strength of yarn is especially important.

Species and Varieties of Cotton

There are many different species and hundreds of different varieties of cotton, but the commercial production in different parts of the world is limited to a relatively small number of species. Since certain plant characters and fiber properties are inherited and are peculiar to particular species and varieties, the kind of cotton grown in the different sections of the cotton-producing countries has become very important. The American Upland type (*Gossypium hirsutum*) comprises more than 99 per cent of the acreage planted in southern Brazil, in Central and South Africa, and in Russia; and it comprises a part of the acreage in other important cotton-growing countries. The Egyptian and Sea Island varieties (*Gossypium barbadense*) are also of American origin and are grown rather widely, but only in relatively large acreage in Egypt. The cotton of India and other parts of Asia is of Asiatic origin (*Gossypium herbaceum*), and is usually shorter and coarser than the varieties and strains that have been developed from the American Upland. In all of the cotton-growing countries, there are large numbers of varieties and strains of the particular species that is grown. In the United States, there have in the past been listed as many as 1,200 different varieties or strains. The commercial breeders are producing new varieties every year, and many of the older ones are being discarded. Under the present plan of standardized production in one-variety communities, effort is being made to standardize production on a small number of varieties of superior quality and productive capacity. More than 4,000,000 acres of our production at the present time are in one-variety communities. The bulk of the American crop is now planted to less than 20 varieties. Intensive breeding work has resulted in increase of the average staple length and increase in productiveness of the American varieties. Since certain fiber properties that contribute to use values have been found to be definitely inherited, some of the more progressive manufacturers are buying cotton of particular varieties from standardized one-variety areas for special uses.

Production of Cotton

Cotton is planted in the cotton belt in the early spring, soon after the danger of the frost is over. Like corn or any other intertilled crop, cotton is planted in rows. Practically all work in the cotton fields is done by mule-drawn machinery, with the exception of hoeing and pick-

ing. Tractor cultivation is coming into general use, however, and the number of mules on the cotton farms is steadily decreasing. Mechanical pickers, though not perfected at this time, may eventually be a reality. The perfection of such a machine, in the opinion of some economists, may practically destroy the small cotton grower, just as the combine has limited wheat growing in the Central West.

When cotton is fertilized, the fertilizer is usually applied before planting. The amounts and kind of fertilizers vary with the class of soil A common practice is to use from 200 to 800 pounds of a fertilizer analyzing 4 per cent nitrogen, 10 per cent acid phosphate, and 4 per cent potash In the past, this has cost around $2 per 100 pounds Usually this fertilizer will pay when cotton sells for 10 cents per pound or over. Some cotton is fertilized with a side dressing of nitrogen or nitrogen and potash soon after it is worked out, which as a rule is in the month of June.

Problem of reducing production costs. The farmers of the cotton-producing part of the United States, led by the Agricultural Extension Service of the Colleges of Agriculture represented by the county agricultural agents, are giving much attention at this time to the cost of production and methods for reducing it. They are planting more green manuring crops and adopting other soil-improvement practices; they are using more productive varieties and strains; they are studying cost of production per man as well as production per acre; they are figuring on the exchange value of their products; and they are eliminating waste and making every effort to compete with "big business" in mass production.

Cotton growing. Cotton is planted in rows, which are slightly elevated to insure proper drainage in early spring. From 1 to 1½ bushels of seed are used per acre The land generally is well prepared before the seed is planted, and cultivation is accomplished by two mules drawing a cultivator that works one row completely. When the cotton is 3 to 4 inches high, it is thinned out in hills 12 inches apart with two to three stalks left in each hill. On the best farms, the cotton is worked each week or 10 days thereafter until August 1, or until it gets so large that the implements cannot be run without doing damage to the plants by breaking off limbs and matured fruit. The acreage each laborer is given is limited to the amount that he can work in this length of time.

The cotton plant is unlike a great many crops in that it continues to bear fruit until there is a killing frost. The cotton matures from the ground up, and it is not unusual to see open bolls of cotton and blooms on the same plant. From this statement it can be seen that an unusually early frost in the cotton belt materially decreases the yield. On the other hand, an unusually late frost will add many thousands of bales to the year's crop.

Picking the crop. Cotton picking, which is done by hand labor and is paid for by the 100 pounds, begins in southern Texas in July and in the northern part of the belt 8 weeks later. As a general rule, it takes 1,500 pounds of seed cotton to make a 500-pound bale of lint. The price paid cotton pickers ranges from 50 cents per 100 pounds in years of depression, such as 1931, to $1.50 per 100 pounds in years of easy money

The average cotton picker of the South will gather about 200 pounds of seed cotton a day. Exceptionally good pickers can pick 400 pounds, and records up to 1,000 pounds a day have been made.

Gathering, ginning, and baling. When cotton picking begins on the average farm, the common farm wagon is equipped to hold the amount of cotton required to make a bale. This cotton is gathered in long sacks and emptied into the wagons. When sufficient seed cotton is accumulated, the wagon is hauled to the gin, where the seed is separated from the lint. Enough seed is returned to the farm to plant the following year's crop; and the balance is sold to the gin, which, in turn, sells the seed to the oil mill. The ginner charges 20 cents to 35 cents per 100 pounds of seed cotton for ginning, and from $1.00 to $1.25 for the jute bagging and iron ties that he uses to wrap and bind the bale. There are many gins in the cotton belt owned by the same capital that owns the land, but the larger propertion of the cotton is ginned by public gins that have no interest in the cotton that they are ginning, other than to render satisfactory service and collect a legitimate price for their work.

In standardized one-variety communities, the gin might be owned coöperatively by the community or by an individual who operates it in the interest of the group of growers. In either case, no cotton is ginned except of the particular variety on which the community is standardized In this way, the planting seeds are kept free from mixture with other varieties.

Warehousing baled cotton. After the cotton is ginned and placed in a bale by the gin operators, it is then carried to some form of storehouse. The majority of these storehouses are Federal-licensed warehouses and compresses combined. When cotton is placed in a warehouse, a receipt is issued in the name of the owner. These warehouse receipts are negotiable pieces of paper secured by the stored bales of cotton in question. They are handled by banks, cotton factors, and commercial organizations throughout the South that deal directly in cotton or accept cotton as a basis for credit. These warehouse receipts show the weight of the bale, the grade, and, in many areas, the staple, though this is not common over a large part of the territory.

Shipping cotton. Before the cotton leaves the compress, it is repressed to such a density that it can be stored in a space about one third of that it required when it came from the common gin. In this condition, it is hauled in trucks or shipped in box cars to factories in the United States or abroad. It is a matter of common knowledge that American cotton, as it is prepared today for export, is not a very attractive article, and much could be done to improve its appearance. The export bales are ragged and most unattractive in appearance.

Cotton By-Products

There are numerous by-products of cotton, but by far the most important one is the seed. Cottonseed oil is used extensively in salad dressings, shortening, and similar foods. It is also used in paints

and in making substitutes for rubber and numerous other articles. Cottonseed meal is one of the most valuable stock feeds known, and is used extensively in feeding dairy and beef cattle. The same use is made of cottonseed hulls. The extremely short lint that remains on the seeds as they come from the common gin is too short to spin into cloth and is known as "linters." This, after being removed by the cottonseed-oil mill, is used in making explosives, such as guncotton. Rayon and many other such materials are also made from linters. There has been some experimental work done in trying to make paper from cotton stalks, but, to date, this has not proved economical because of the large supply of paper pulpwood and other materials from which paper can be made.

Marketing Methods

The marketing of cotton is a complicated but well-established process. There are several methods commonly used in the South today. According to the oldest method and also the one that handles the larger proportion of the crop, the grower, after placing his cotton in the compress or warehouse, takes his warehouse receipt and a sample of his cotton and sells to the local cotton buyer, who attempts to value the cotton, taking into consideration grade and staple and other factors that determine quality and value. In many cases, the growers sell their cotton to the local buyers directly from the gin yard or from the wagon on the street.

Another common method, which is practiced by the larger growers, is to display the samples of cotton on a table in their own offices or in the office of some cotton broker. Cotton buyers visit these tables and buy the cotton for which they have orders. If the cotton is on the table of a broker, the broker receives a small fee for the service that he has rendered.

The third and newest type of sales agency is the coöperative association. Some of the largest and many of the smallest cotton growers of the South belong to these organizations. The coöperative associations are incorporated. They are farmer-owned and farmer-controlled. They have, in their employ, some of the best-trained classers and salesmen that can be found in the cotton industry. These organizations have regulations whereby the grower can consign his cotton to his association and receive an advancement up to 90 per cent of the value of the cotton at the time of delivery. He uses this to pay off his indebtedness, to liquidate any other claims, or to meet expenses. The remaining 10 per cent is paid him at the end of the season, after deducting the actual cost of operation of the association. It is the theory that a farmer who puts his cotton in an association is assured that it will be sold according to grade and staple. He is also assured of receiving the average market price. He does not receive the highest price for the year, but neither does he receive the lowest.

In one-variety communities, the ginner often buys the crop from the individual growers and sells it in large even-running lots to cotton mills

or to brokers. In other cases, the ginner handles the cotton on a coöperative basis for the community.

World Competition in Cotton

Prior to about 1935, the United States had been able to dominate the world cotton market, but this power has been seriously threatened by the competing countries of the world. During the period from 1910 to 1914, the United States produced 62 per cent of the world's crop. In 1930, we produced only 53 per cent of the total; and in 1933, the total foreign production (13,843,000 bales) was slightly larger than the United States crop (13,047,000 bales). Every year since 1933-1934, foreign production has exceeded that of the United States. For 1938-1939, our crop was about 12,000,000 bales, while the total foreign production was about 17,000,000 bales.

Outside of the United States, the largest producing countries are India, with from 4,000,000 to 5,000,000 bales; Soviet Russia, with from 3,000,000 to 4,000,000 bales; China, with from 2,000,000 to 3,000,000 bales; Egypt, with from 2,000,000 to 2,500,000 bales; and Brazil, with about 2,000,000 bales a year. While Russia increased her cotton production from less than 1,000,000 bales during the period from 1910 to 1914 to 3.800,000 bales in 1938-1939, the entire crop is consumed in that country. On the other hand, a large part of the Indian crop, almost all the Egyptian crop, and about one half the Brazilian crop are sold to other countries. Brazil has doubled her cotton production during the past 6 years and has large areas of undeveloped land that would be suitable for cotton production There are about 60 countries that grow some cotton. Increases in production in many of the minor producing areas have greatly added to the total supply and increased the world surplus. Between 1920-1921 and 1937-1938, Peru increased her production from 175,000 to 415,000 bales. During this same period, Argentina increased her production from 25,000 to 238,000 bales, Mexico hers from 100,000 to 340,000 bales, Sudan hers from 25,000 to 260,000 bales, Turkey hers from 95,000 to 300,000 bales, and Uganda hers from 70,000 to 350,000 bales.

Methods of Financing the Cotton Grower

The cotton grower in the United States is financed in a number of ways. By far the largest percentage of cotton is grown by the small farmer, who: (1) finances himself from the sale of other products of the farm; (2) borrows cash from the Federal Loan Agency, a local bank, the gin, or Cotton Financing Company; or (3) is supplied by the supply merchant. The supply merchant operates in many different ways, but usually he begins to furnish credit to the small grower by March 1 in the middle of the cotton belt, and earlier in the extreme southern part. The farmer goes to the merchant and makes arrangement for the amount of credit he needs In arranging for this credit, as a rule, he gives a

mortgage on his crop and everything else he has. This indebtedness is liquidated in the fall. However, if the farmer does not have sufficient income to pay his indebtedness, the merchant, at his option, closes the farmer out or carries the balance into the new year. This is a matter for the merchant and farmer to decide. Of course, there are numerous farmers throughout the South who have money in the banks that they use for operating expenses. In another type of financing, which is fast disappearing, the large grower secures money from what is known as a "cotton factor." The cotton factor, in turn, takes a mortgage on the crop similar to the mortgage that is taken by the supply merchant from the small operator. In this case, the farmer sends his cotton to the cotton factor, who sells this cotton for him and applies the proceeds to the indebtedness. In some sections, Cotton Financing Companies have taken the place of the cotton factor, and provide both cash and certain supplies to the farmer during the growing season.

Operation of the Cotton Plantation

Although the bulk of the cotton grown in the South is raised by the small producers, much has been written about the large cotton plantations. These plantations are worked in the main by Negro labor. They are found in the delta of the Mississippi River, in Arkansas, Mississippi, and Louisiana. Situated somewhere at an advantageous spot will be seen the plantation headquarters, which, as a rule, consist of a store, a residence for the supervising forces, and the gin where the plantation cotton is cared for At one time, this store was the place where the tenants obtained groceries, clothing, and the other necessities of life, which were charged to their accounts. This system is going out of use, however, for now each tenant usually receives a check or cash monthly, and the store has to compete with other mercantile establishments in getting as much of this money back as possible.

The large plantation employs three types of laborers First, there are the day laborers, who work for the owner or operator of the plantation by the day and receive pay each Saturday night for the time put in that week. The second type of laborers are the half-hands. When this kind of labor is employed, the landlord furnishes the land, mules, and other equipment necessary for the growing of a crop, and the half-hand furnishes the labor, for which he receives one half of the sale price of all crops grown or sold. As a matter of fact, he grows very little but cotton, because this is the only crop that he personally is interested in. If he so desires, however, the landlord is perfectly willing for him to grow corn, potatoes, and other crops. In fact, the landlord has come to realize that it is important that this half-hand have a good garden and be as nearly self-supporting as possible. The third and most dependable type of labor for the large farm is that which rents either for money or for a share of the crop. Laborers of this class are called "renters." The landlord furnishes the land only, and the renter furnishes the mules, plows, seed, and everything else incidental to the growing of

the crop. If he pays a crop rent, the landlord receives one fourth of the cotton and, as a rule, one third of the corn.

In a general way, it might be said that the day laborers on large plantations are the young Negroes—mostly sons of the renters—the share croppers are the young married Negroes, and the renters are the older settled families. In other words, the laborers on these plantations progress. First, they are day laborers; second, they are half-hands; and third, they are renters. When the disparity between the price of cotton and the price of things that the farmer must buy is not too great, the more thrifty ones save enough money so that, by the time they are 50 years old, they can buy a small farm and be comparatively independent There are numerous Negroes throughout the South who own large and small farms, according to their ability. Of course, it is generally understood that the majority never reach this stage. However, this is not because the opportunity for acquiring land is not available in practically every locality.

Cotton Pests

The cotton crop is affected by a number of insects, the most serious of which at this time is the boll weevil. The injury caused by this pest is being overcome by using early-maturing, rapid-fruiting varieties of cotton and by the use of fertilizers and cultural practices that hasten maturity. The use of calcium arsenate as a weevil poison is usually effective, but the results are not always satisfactory, and the expense of equipment needed for the operation discourages its use. The cotton-leaf caterpillar, another insect that defoliates the plants, can be easily controlled by any arsenical poison. Red spiders are controlled by dusting with sulphur. The cotton pink bollworm, a pest much dreaded by the cotton farmer, is being successfully confined in the limited areas that it infests by a rigid quarantine established by the state and Federal governments.

The cotton crop of the United States is affected, not only by insects, but also by a number of diseases, such as boll rot, leaf spot, and wilt. These diseases are being studied by the Agricultural Experiment Stations and can be controlled to a limited extent.

12

The Rubber Industry

The Early History of Rubber

Discovery. Legend has it that the first white man to come into contact with rubber was Christopher Columbus. It is believed that on his visit to the island of Haiti in 1492, he noticed Indian boys playing a game with an elastic ball. He learned that the ball was made from a milky substance obtained by cutting the bark of a certain tree, and that this substance upon contact with air tended to darken and harden and become an elastic mass.

When the Portuguese colonized Brazil, they discovered in the valley of the Amazon River great numbers of the trees from which this same milky substance could be procured. This substance is known as "latex" and contains the rubber of commerce, besides water and other material. It is found in special elongated cells in the inner bark of the tree. When the bark is cut, these cells are severed and for a short time the latex flows freely. If, in cutting the bark the "quick" of the tree (cambium layer) is not injured, the bark renews rapidly.

A Frenchman named La Condamine, who was a member of a South American expedition, sponsored by the Paris Academy of Science in 1731, in his diary mentioned "Hevea" trees, from which was obtained a liquid used by the Indians in making crude waterproof clothing, boots, and water bottles.

Early methods of procuring and treating rubber. When commercial demand for articles made of rubber developed, the only source of the raw material was in the jungles of Brazil, where the rubber trees grew wild. The only means of penetrating these jungles are the waterways of the region. While these permit access to the places where the rubber trees flourish, they also prevent the gathering of rubber because during the rainy season each year, from November to May, they overflow their banks and flood the surrounding country, making it impassable.

Therefore, at the end of the rainy season, bands of natives equipped with food supplies and other necessities for their labor went by boat or canoe up the Amazon River and its tributaries and established central camps in the rubber regions. Each tapper, as he was termed, was allotted a certain number of trees to be visited and tapped each day, these

being arranged in a regular route. The native tapper would go into the forest and with a hatchet gash long wounds in the rubber trees, placing small receptacles at the bottom of these gashes to catch the milky latex which oozed from the wounds. After having tapped possibly 70 to 100 trees, the tapper would go back over his route collecting in a large pail the latex that had flowed into the smaller receptacles on each rubber tree. This pailful of latex then was taken to the central camp where the tapper built a fire of wood and specially collected palm nuts, over which was placed a clay flue to concentrate the smoke. By pouring a little of the latex on a long wooden paddle and rotating the paddle in the hot smoke from the fire, the liquid was evaporated from the latex, leaving as a residue on the paddle a thin layer of pure rubber. By continuing this process there was built up layer upon layer of rubber until there was formed a large mass, usually termed a "biscuit," about 10 inches in diameter and 1½ to 2 feet long, weighing in the neighborhood of 70 pounds, representing a day's work for the tapper. At the end of the dry season, the native tappers would take the biscuits to the primary rubber markets at the sea coast and sell them to representatives of American and European rubber importers.

Early uses of rubber. The earliest known use of rubber was made by the natives in the Amazon Valley, who devised crude waterproof boots by pouring latex on their feet and legs and permitting it to oxidize in the sun. By spreading a thin film of latex on cloth and hardening it by exposure to sunlight, or by smoking it, the natives were able to make rather crude but quite effective waterproof garments. They also made vessels for holding liquids.

To Dr. Joseph Priestley, the English scientist who discovered oxygen is given the credit for applying to this elastic substance the name by which English-speaking people know it. Happening to obtain a ball of the hardened gum, he found it would erase pencil marks, which suggested to him the name "rubber."

In 1823, an Englishman named Charles Mackintosh discovered that he could waterproof garments by putting a layer of rubber dissolved in coal naphtha between two fabrics. The name "mackintosh" is still used by many people when referring to cloth-surface raincoats.

Another pioneer English manufacturer of rubber goods was Thomas Hancock, who utilized rubber in the production of air pillows, mattresses, hose, waterproof mail bags, carriage tires, and numerous other products. The year 1832 witnessed the establishment of the Roxbury India Rubber Company in Roxbury, Massachusetts, the first American manufacturing plant to produce the same line of rubber articles as made in England.

History of the Rubber Industry in the United States

All of the early manufactured rubber articles had one basic defect—they were very sensitive to temperature changes. When exposed to heat they would become soft and sticky and even melt, while cold made them hard and stiff.

Discovery of vulcanization by Charles Goodyear. An American named Charles Goodyear is generally recognized as the man who really discovered how to overcome this difficulty. After experimenting for nearly 10 years trying to find a means of rendering rubber firm and yet flexible regardless of temperature, in January, 1839, he reached the solution of his problem. He accidentally dropped upon a hot stove part of a mixture of rubber, white lead, and sulphur. Upon examining the resulting charred lump, he noticed that through its contact with heat a change had taken place in it. When it cooled, Goodyear found it could be bent and easily stretched without breaking and that despite repeated stretching it would always snap back to its original shape. It was no longer sticky, nor did exposure to extreme cold make it stiff. The process he had discovered he termed "vulcanization," after the Roman god of fire, Vulcan.

Early beginnings of the industry. Following Goodyear's discovery of the method for overcoming the basic deficiency of products manufactured from rubber, there began to appear throughout New England *factories engaged in the manufacture of rubber boots and shoes and* waterproof fabrics. The number of these factories slowly increased as the public began to become familiar with the possibilities of utilizing rubber in connection with the economic and social life of the nation. With the invention of the automobile and the adoption of mass production methods which made it possible to manufacture at prices within the means of millions, rubber factories sprang up throughout the country to supply this new industry's requirements of tires, tubes, and other accessories.

Leaders in the rubber industry. Many prominent men have been identified with the rubber industry, but perhaps the outstanding personages who have contributed most to the development of the industry are: Charles Goodyear, Dr. B. F. Goodrich, Colonel Colt, F. A. Seiberling, H. S. Firestone, and George Oenslager.

Rubber Plantations

General geographical location. As has already been stated, rubber trees grow wild in the Amazon Valley and other portions of South America having a similar hot, damp climate. These trees require high humidity and heavy rainfall and a uniform temperature of about 90 degrees during the day and not lower than 70 degrees during the night. Climate of this sort is found only between latitudes 30 degrees north and 30 degrees south of the Equator, and this zone extending around the world between these parallels is known as the "Rubber Belt." The greatest amount of rubber used commercially, however, comes from what is termed an "Inner Rubber Belt," which extends between latitudes 10 degrees north and 10 degrees south of the Equator. This belt includes not only the Amazon Valley, but portions of Bolivia, Peru, and Venezuela in South America; Belgian Congo and Liberia in Africa; Ceylon, in the East Indies, and the Philippine Islands in the Pacific Ocean.

Shrubs containing rubber. Besides the rubber trees, there are numer-

ous shrubs containing rubber. The chief of these is guayule, a native of Mexico. Through the efforts of an American company, this shrub has been cultivated on large plantations in Mexico, and in recent years it has been introduced into southern California.

First cultivated rubber trees. Prior to 1876 the principal source of Hevea rubber, the variety which enjoys chief commercial demand, was the Amazon Valley. An Englishman, Sir Henry Wickham, was familiar with the difficulties of gathering rubber in the Brazilian jungles and was aware of the growing resentment among rubber manufacturers because of the Brazilian Government's maintenance of high rubber prices through artificial means. He also knew that manufacturers were becoming increasingly dissatisfied with the way in which rubber reached the market, for it usually contained dirt, bark, and other impurities, and there was great variation in quality. Wickham conceived the idea that rubber trees could be cultivated on the coffee plantations in India, where the soil and climatic conditions were similar to those in the Amazon Valley where wild rubber trees flourished. He succeeded in eluding the vigilance of the Brazilian Government by smuggling out of Brazil a large quantity of carefully selected and packed Hevea seeds, which he caused to be planted in the Botanical Gardens in Kew, near London, England. When the seedlings had sprouted, they were sent to Ceylon for planting. In 4 years they were ready for tapping, and so demonstrated the value of Wickham's idea.

Present-day great rubber-producing areas. From this small beginning has developed the present acreage of rubber plantations in the Middle East, where it is estimated that more than 8,000,000 acres of cultivated rubber trees now constitute the world's principal rubber-growing region. This region comprises the Malay Peninsula, that portion of Siam included in the Malay Peninsula, the Islands of Ceylon, Sumatra, Java, and Borneo, French Indo-China, and Burma in British India.

In 1900 only 4 tons of plantation rubber were produced, as compared with 26,750 tons from Brazil and 27,000 from other countries in South America and Africa, where wild rubber flourishes. In 1939 *plantation* rubber production amounted to 975,000 tons, as compared with 16,000 tons of wild rubber from South America and 9,600 tons from other wild-rubber-producing countries.

The site of a rubber plantation is of vital importance since the rubber tree requires favorable climatic and soil conditions and there must be available a stable labor supply and convenient shipping facilities.

Approximately 97 per cent of our total imports of crude rubber now come from the Middle East (British Malaya, Netherlands Indies, Ceylon, French Indo-China, British India, Thai, and so forth). African plantation rubber and wild rubber from tropical America account for most of the balance. More than 8,500,000 acres are planted with crude rubber in the Middle East area, approximately all but 350,000 acres of which are now in bearing. The area has a potential current annual productive capacity of at least 1,800,000 tons. Since 1920 the per-acre average pro-

duction has increased from 400 pounds to 500 pounds in 1940. Bud grafting and more scientific planting methods are constantly raising this average. In the near future there will be nearly 1,000,000 acres of grafted rubber having an average yield of 1,000 pounds to the acre.

Two extremely important effects of this greatly expanded acreage and per-acre output have left their mark on the rubber manufacturing industry during the past 20 years: (1) a violently fluctuating price until the last 6 years; and (2) producer export and output control.

In 1919 the average New York price of ribbed smoked sheet was 48.7 cents per pound. By 1921 the price had fallen to 16.4 cents per pound, before beginning a climb to an average of 72.5 cents per pound in 1925 under the Stevenson Restriction Scheme and falling to the average 1932 depression low of 3.4 cents. In 1939 the average price was 17.5 cents. In many individual years the spread was greater than is indicated by these annual averages, touching for instance a high of $1.23 in 1925 and a low of 2⅝ cents in 1932. For much of the twenties and early thirties the rubber manufacturing industry of necessity found that gambles with crude-rubber price trends outweighed in the financial statements gains or losses in finished product sales. A real need was felt for reasonable price stability.

The first producer attempt to control prices, the Stevenson Scheme, failed because it was not sufficiently inclusive. The artificially high prices produced by this control effort had actually the opposite effect, and huge new production acres were planted during the pre-1929 years. Much of this acreage came into bearing when the demand for crude rubber dropped with automotive production in the early thirties. The resulting price collapse was so complete that in 1934 the International Rubber Regulation Committee was set up, composed of representatives of British, Dutch, French, and Thaian producers in the Middle East, and encouraged by the governments of those countries which signed a treaty giving effect to a producers' agreement outlining a joint method of export control. An Advisory Panel of representatives from leading consuming countries was appointed to offer advice and furnish information on likely consumption trends to the International Committee; basic quotas for each producing country were set up, and regular committee meetings arranged to fix "permissible exportable allowances" of the basic quotas which could be shipped in ensuing quarters or 6-month periods.

In so far as the effect of the formation of the International Rubber Regulation Committee on the American manufacturing industry is concerned, it would seem that we have benefited from a relatively more stable price and undergone a period of sharply declining stocks Our low point in stocks was reached in November, 1939, when we had 105,205 long tons on hand. At the end of July, 1940, our stocks had risen to 190,222 on hand, as well as 139,629 afloat. (In July, 1939, we had only 52,990 tons afloat.) The trend is now definitely upward.

Preparation for planting. In preparing for the planting of rubber trees, it is necessary to clear away the dense tropical jungle and other vegetation, after which rubber tree seedlings are transplanted on the

cleared area. Native labor is employed for these operations and for subsequent cultivation of the rubber plantations, including the cutting back of jungle growth which might impede the growth of the rubber trees, or the planting of cover crops between the trees to keep down jungle growth, as well as the fertilization of the soil and necessary ditching and draining to assure proper irrigation and to prevent excessive soil erosion during the rainy season.

Plantations range from the large ones of thousands of acres in area, generally controlled by European capital, to the small gardens of the native population, ranging from a fraction of an acre to 100 acres or more. Substantially the same methods are employed in native gardens as in the large estates, except that the former are more densely planted and usually are interspersed with such indigenous crops as rice, pineapples, cassava, and so forth.

Modern Methods of Procuring and Preparing Latex for Manufacture

Tapping the trees. When rubber trees reach the productive age of 4 or 5 years, they are tapped by carefully making with a very sharp, thin, specially designed knife a diagonal incision the depth of the bark, from a quarter to halfway around the tree, about 18 inches from the ground The original wound is widened in subsequent tappings by stripping off, in the same manner, very thin slivers of bark; it is essential that the incision should not extend into the woody part of the tree. The latex or liquid rubber flows from this wound into a cup at the end of the incision, which heals when the tree has given up all the available latex from the particular cutting.

Manufacture of rubber. The latex is collected and taken to a central station where the particles of rubber are extracted by pouring the latex into containers, to which acetic acid is then added. This causes rubber particles to coagulate and come to the surface in a thick sheet. Foreign matter such as chemicals, bark, twigs, dirt, and so forth, is removed by tearing the coagulated mass of rubber to pieces in a machine, after which it is washed and passed between ribbed rollers which compress the mass into sheets of uniform thickness. These rubber sheets are then dried and smoked for a period of approximately 2 weeks. This process imparts to them a dark-brown color, which accounts for their designation Ribbed Smoked Sheets. Another grade of rubber known as Pale Crepe is produced from the basic latex by adding to the coagulating agent, acetic acid, a small quantity of sodium bisulphite. In the case of this grade, the coagulated rubber emerges from the washing machine in a rough, irregular sheet and is hung in a drying room while still wet. In this drying room the sodium bisulphite exerts a bleaching effect on the rubber, and it emerges pale yellow in color, which accounts for its designation. Through less efficient methods are produced grades of rubber that contain some impurities such as rosin or bark, which necessarily result in a lower quality classification. The chief standard classifications of rubber are Ribbed Smoked Sheets, Latex Crepes, Brown Crepes, and Blanket Crepes,

which, in turn, are subdivided into numerous qualities of each grade.

Principal rubber markets. Upon completion of the manufacturing process, the large sheets are reduced to smaller sizes measuring approximately 25 inches long by 15 inches wide, which are packed in wooden cases, burlap, or matting-covered bales and shipped to the markets where trading in rubber takes place. The principal primary markets are Singapore, Penang, Colombo, Batavia, and Medan; Amsterdam, London, and New York are the leading secondary markets.

Shipping rubber latex direct. There have recently been perfected methods of shipping rubber latex direct to rubber manufacturing plants in the United States. This is done by treating the latex with ammonia as a preservative and shipping it from the Middle East in drums or in the ballast tanks of vessels. In the latter case it is transported from the seaport to the factory in tank cars.

Converting latex by flaking. Still another method of converting latex on the plantation is by "flaking." This process, developed by an American-owned plantation, consists of permitting a thin stream of latex to flow from a tank upon a rapidly rotating heated disk located near the ceiling of what is known as a spraying room. This disk, by centrifugal force, throws off the latex in a spray of separate drops. The high temperature of the room evaporates the moisture in the latex drops and the remaining pure rubber particles fall to the floor in flakes resembling snow. This "snow" is pressed into compact blocks, given a protective packing, and shipped to rubber manufacturing plants in the United States.

Geographical Location of the Rubber Manufacturing Industry

First rubber factories located in New England. In reviewing the history of the rubber manufacturing industry it is rather difficult to account for the development of the different rubber manufacturing centers. The first rubber factory in the United States was the Roxbury India Rubber Company, Roxbury, Massachusetts, founded in 1832. Another plant was built in Springfield, Massachusetts, in 1841 to carry out Charles Goodyear's ideas following his discovery of vulcanization. Consequently, it was probably natural that the industry should first develop in that vicinity. Contributing causes may have been the fact that New England was then the manufacturing center of the United States, had developed power facilities, and possessed a skilled labor supply. Probably another prominent reason for the development of rubber manufacture there was the fact that the first products were principally footwear and rubber clothing, which naturally were marketed in the centers of greatest population, which were then in New England and adjacent states.

Footwear factories in New Jersey. Beginning about 1858 there was a development of footwear factories in the state of New Jersey due, primarily, to proximity to centers of population and to seaports through which raw materials were imported and finished products exported.

Location in the Middle West. The movement to the Middle West originated in about 1870, owing in a large measure to Dr. B. F. Good-

rich's belief in the future of rubber manufacturing and the enterprise of businessmen in the Akron, Ohio, district. This was quite a fortunate choice because of the subsequent development brought about by the invention of the automobile, although it is probable the deciding influence in this movement may have been the proximity of the carriage-making industry, to which rubber manufacturers supplied pneumatic and solid tires. When these Middle Western carriage manufacturers metamorphosed into automobile manufacturers, they found a source of tires already developed in adjacent territory in Ohio, so it was quite natural that the Akron, Ohio, manufacturers should develop in so astounding a fashion to the huge corporations of today.

In the past the tendency has been toward centralization of manufacture, but in more recent years there appears to be a tendency toward decentralization for economy in distribution. This is evidently one of the reasons for the newly developed manufacturing center in Los Angeles, California, and the possible future development in the South, which also has the advantage of near-by cotton supply, in addition to low labor and power costs.

Location in foreign countries. The tariff barriers erected by various foreign countries undoubtedly have had a decided influence upon the development of rubber factories in this country. These barriers have forced American manufacturers to build factories in such foreign countries to protect their export business developed over a period of years. Without such tariff barriers, it is logical to suppose there would have been a further expansion of existing American rubber factories to care for the constantly growing and profitable export trade in rubber products.

Modern Methods of Rubber Manufacturing

The initial steps in producing entirely dissimilar finished rubber articles are surprisingly similar. This is due, primarily, to the nature of the raw material, which requires certain preliminary treatment prior to use in any definite form.

Cutting and refining. After removal of crude rubber from storage at a rubber plant, it is taken from the shipping container or covering and sliced into easily handled segments. When the lower grades of rubber are used, it is necessary to wash and dry and otherwise refine the crude rubber to eliminate foreign matter.

The washing is done on a machine called a "cracker," which consists of two horizontal, parallel steel rolls with corrugated surfaces operated in a fashion similar to the ordinary washing wringer. The action of the rolls softens the mass upon which streams of water constantly spray to wash out the foreign matter. The resulting rubber mass is then dried in vacuum heaters and, if the quality is very poor, is further refined in another wringer type machine having smooth rolls. To insure absolute purity of rubber required for use in high-grade compounds, it is often necessary to strain the rubber mass by forcing it through a strainer die inserted in a tuber-type machine.

Mixing the compound. The cleaned rubber now passes to the compounding room, where skilled workers make up the batches of material necessary for manufacture of specific products. The batch recipes are furnished by the laboratory, where they have been carefully formulated. The required quantity of rubber, a vulcanizing agent, the various other chemicals which have been developed in recent years to hasten vulcanization, the pigment necessary to produce the desired color, and any filler material to govern the required density of the finished product and its elasticity are all carefully weighed and placed in a wooden or steel receptacle.

Here, also, "reclaimed rubber" may be introduced. As its name implies, this is a substance obtained by abstracting the rubber content of scrap or worn-out rubber products after treating them to eliminate fiber content and to "devulcanize" the rubber atoms by getting rid of their sulphur content. Reclaimed rubber has an important and legitimate place in the manufacture of certain rubber products, particularly where maximum tensiles are unnecessary, but in which toughness or resistance to abrasion is needed. The designation "reclaimed" does not imply an inferior ingredient, but rather a different sort of rubber which may be advantageously utilized in the fabrication of certain types of rubber products.

The batch is taken to the mixing room, which houses mills or mixers of various sizes or types. The most usual type is the roll mill, which is similar to the ordinary washing wringer, with two horizontal, parallel, smooth steel rolls These rolls are geared to operate at different speeds, and create a wiping action upon the material passing between them. The crude rubber in each prepared batch is first placed on the mills and softened by the heat or friction caused by the various speeds of the rolls Then the other chemicals and pigments are added and thoroughly mixed into the plastic rubber mass by the wiping action of the rolls. The mixed stocks are taken from the mill in slabs or sheets, ranging from 1½ inches to 1 inch in thickness. These slabs are covered with either a liquid or dry solution of soapstone or talc to prevent adhesion.

Processing for particular products. From this point processing differs according to the type of product or component parts of the products manufactured. If a sheet of solid rubber is desired, the compound is passed over what is known as a calender, or deck, of steel rolls with pressure exerted on the rolls. Prior to introducing the compound to the calender, it must be softened or warmed on a warming mill so that it will feed evenly through the calender, the rolls of which have been set to give the desired thickness. The sheet of compound is then reeled on what is known as a shell and liner; the shell is merely a core or reel, while the liner is a length of fabric used to prevent the sheeted compound from adhering to the previous layer. If a friction fabric is required—that is, a piece of fabric impregnated with rubber—a calender is also used and a certain amount of pressure is exerted to press the rubber into the spaces between the warp and woof of the fabric to give the required weight per square yard according to the desired thickness. If the surface of a cloth

is merely to be coated or covered with rubber, a spreading machine is used which consists of an adjustable "spreading knife" and a table of steam pipes. The proper compound is selected and reduced to a cement by diluting with gasoline to the consistency of thick glue. This solution is applied on the spreading machine in front of a "knife" brought down within a predetermined distance from the cloth before it passes over the steam table. The cement feeds evenly under the "knife" over the entire width of the cloth, coating it very lightly. By the time the cloth is reeled at the end of the steam table, the gasoline in the solution has evaporated. If a heavy coating is desired, the same fabric must be run over the spreading machine several times until the desired thickness or gauge is reached.

In the manufacture of certain types of hose or tubing, as well as a great many varieties of solid rubber strips, a tubing machine is used rather than a calender or spreader. The tubing machine is one with a die orifice the shape of the desired finished product, through which the previously warmed compound is forced under pressure, thereby extruding the hose, tubing, or strip in the form desired. Some solid tire treads are manufactured in this way, as well as hospital tubing, baby carriage tires, and tubes for various cotton reinforced hose.

Shaping the product. At this point the shaping of the product begins. In the case of tires and footwear, the material must be cut into the desired shape and size in a so-called cutting room. The cut material next is built up or assembled over a core or last in a fabricating department.

When the product has been shaped and made into its final form, it is enclosed in a mold so that upon vulcanization the dimensions and shape will be permanently fixed and any design cut into the side of the mold will be embossed on the finished article. In the manufacture of automobile tires, an air bag is placed inside the tire. This air bag is substantially a heavy-duty rubber inner tube inflated with air, which expands under heat and forces the outer surfaces of the unvulcanized casing against the surrounding cast iron mold, into the inner surface of which the tread design and other desired impressions or lettering are cut. A similar procedure is followed in producing various types of drug sundries, such as hot water bottles, where a cast iron inner mold is used and the whole is inclosed in an external mold having the desired impressions cut on its inner surface. Rubber footwear is usually vulcanized by being placed on racks in ovenlike chambers before removing the lasts and curing under open heat.

Many rubber products, such as hard rubber battery containers, are manufactured by merely cutting up blocks of raw compound, not necessarily in the shape of the finished article, but merely of the proper volume to fill a given mold cavity. Others are made by cutting with a die to the approximate size of the mold cavity. This is true of rubber heels, which are cut out in approximately their finished shape, much as biscuits are formed with a biscuit cutter. These heel "biscuits" are inserted in the mold cavities cut to the exact size of the finished product desired.

Rubber gloves, toy balloons, finger cots, and other thin rubber par-

ucts are manufactured by dipping forms of the desired shape and dimensions into a tank of rubber cement. The dipping is usually performed mechanically by utilizing a number of forms at the same time. The thickness or gauge of the rubber deposit is governed by the number of times the form is dipped.

Since the development of pure latex concentrates, gloves for surgeons' use, as well as the best quality products, are now manufactured by dipping forms in latex solutions rather than rubber cement.

In manufacturing sponge rubber products, special bubble-forming compound ingredients are used. After compounding and mixing, the quantity of compound necessary to fill each mold cavity is carefully determined without regard to the shape of the cavity. No assembling operation is required. The press type of vulcanizer is used without pressure, however. The special ingredients in the compound form bubbles when heat is applied, swelling the compound to the outer extremity of each mold cavity. After vulcanization, the bubble cells are permanently fixed.

*A newer type of sponge known as the foam or whipped sponge is manu*factured at the present time directly from liquid latex. The ingredients are whipped and the mass of bubbles thus formed is vulcanized into the desired shape. This development may revolutionize the mattress and upholstery business, as it lends itself to shaping in any form and furnishes a luxuriously soft cushion for chair, car, bus, and theater seats as well as for ordinary mattresses.

Vulcanizing. All of the products and processes just described require some form of heat with steam as the vulcanizing agent. These heaters are sometimes in the form of large, steel tanks into which the filled molds are introduced and the heaters sealed. By the introduction of live steam the product is "cooked" or vulcanized in or on its mold for the required length of time.

Other types of products, such as rubberized raincoat materials, are vulcanized either in what is known as an open heater or by an acid process. In the open-heat process the rubberized fabric is festooned in a large ovenlike vault lined with steam pipes; the doors are closed and sealed, and dry steam heat is applied for a given length of time. In the acid process, the material passes continuously through a form of acid bath, or is placed for a given length of time in some form of tumbling barrel or drum containing acid. The same results accrue as in the steam method, but the acid process can be used only for certain types of products.

Finishing. Most rubber products require some form of finishing. Where the article has been cured or vulcanized in molds under pressure, there is always a slight seepage of excess compound called "rind." This must be trimmed off by a method developed for the particular product The crudest method is hand pruning by a specially designed knife, while one of the most highly developed methods is the delicate machine used for trimming rubber heels.

Certain products require some form of exterior surfacing to make

them more attractive. In the case of boots and the ordinary rubber, a varnish is applied prior to vulcanization. This is also true of various types of drug sundries where a brilliant gloss is desirable. Tires are

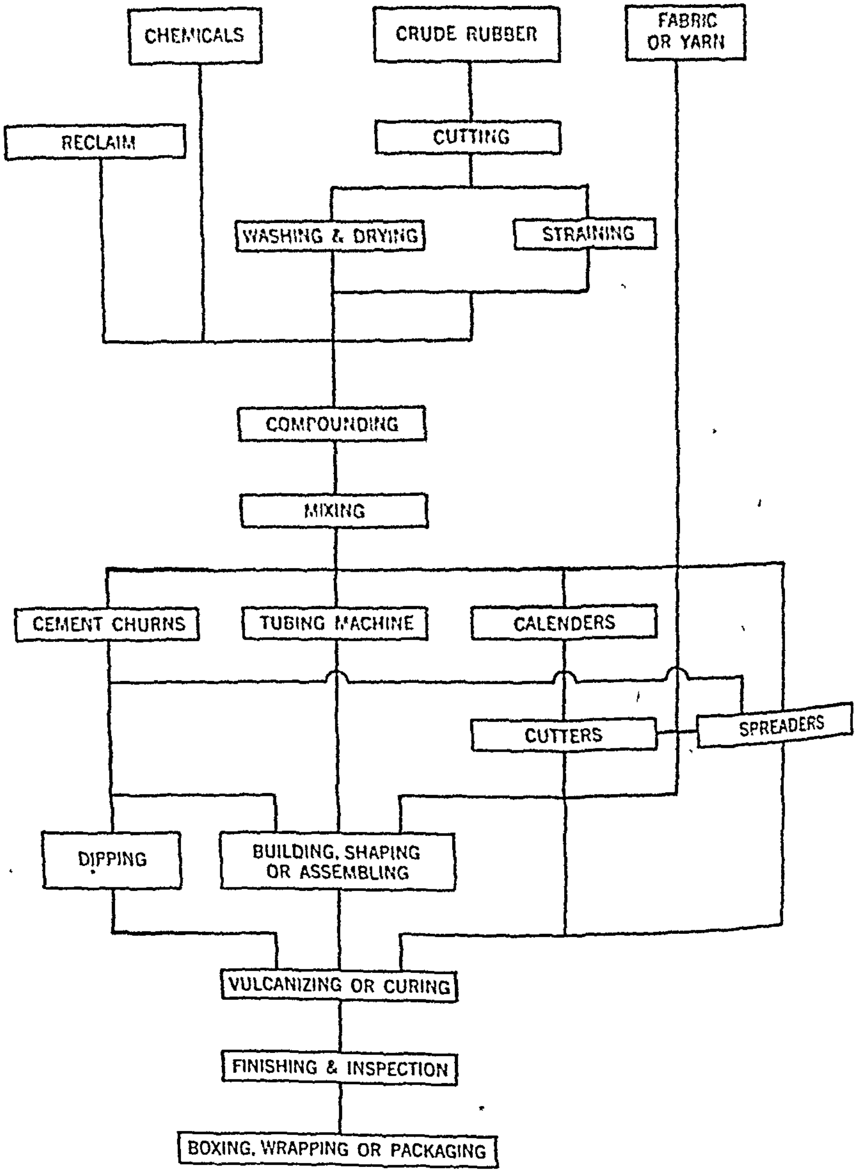


Fig. 1. Material flow in a rubber factory.

sometimes washed and painted after vulcanization; at least a stripe or identifying seal is painted on the tire with a spray. Some hard rubber articles are given a glossy, polished surface by curing between sheets of tin under pressure, or by buffing after vulcanization.

The accompanying material flow chart graphically illustrates the important steps in the manufacture of rubber products.

Rubber Products

There follows a list of the most important rubber products, with accompanying figures regarding the volume or value of their 1937 production:

CENSUS OF MANUFACTURES FOR 1937

Manufactures	*Production Units*	*Sales Value of Production*
Pneumatic tires and casings—motor vehicles:	—	—
Passenger car	45,668,599 tires	$253,270,878
Truck and bus	7,702,436 "	156,459,385
Airplane	32,710 "	667,985
All others	709,700 "	2,367,550
Motorcycle and bicycle:		
Single-tube tires	1,654,216 "	1,390,700
Casings	3,402,263 casings	3,191,864
Inner tubes:		
Passenger car, truck, and bus	52,372,908 inner tubes	55,739,387
Airplane	25,026 " "	101,912
Motorcycle and bicycle	3,397,286 " "	1,186,697
All others	167,906 " "	470,135
Solid and cushion tires:		
Truck and bus for highway transportation	22,697 tires	875,920
Industrial truck, tractor, and trailer	232,297 "	1,547,769
All other, including carriage and other tiring	13,566,853 "	1,500,715
Boots and shoes:		
Total rubber-soled canvas	31,519,085 pairs	18,042,154
Total waterproof	45,482,797 "	40,227,104
Rubber heels, soles, and strips:		
Heels	295,081,194 "	16,285,139
Soles	72,476,284 "	10,750,044
Strips	8,072,411 "	2,075,999
Rubberized fabrics:		
Automobile and carriage fabrics	6,006,465 sq. yds.	2,122,853
Raincoat fabric	21,374,062 "	4,873,452
Hospital sheeting	2,982,123 "	1,072,522
All other rubberized fabrics	39,252,005 "	13,562,630
Mechanical rubber goods:		
Rubber belting		
Transmission (flat)	21,793,187 lbs.	13,381,938
Conveyor and elevator	15,759,803 "	6,901,352
Fan belts	14,443,005 "	8,291,974
All other belting	6,710,485 "	3,484,641
Rubber hose:		
Garden	46,932,725 "	7,058,709
Fire hose	9,345,767 "	4,726,025
Air brake, air line, and other pneumatic	13,486,496 "	4,914,841
All other rubber hose	65,460,793 "	19,218,945
Rubber tubing	22,961,182 "	4,491,613
Rubber packing	14,046,511 "	3,550,830
Washers, gaskets, valves, *etc.*	15,017,089 "	5,035,917

CENSUS OF MANUFACTURES FOR 1937 (*Continued*)

Manufactures	*Production Units*	*Sales Value of Production*
Insulation products:		
Rubber and friction tape	21,112,965 lbs.	$1,538,355
Molded articles for motor vehicles	60,420,110 "	13,223,211
Other insulation products	10,590,082 "	2,893,880
Rubber covered rolls	—	4,851,772
Plumbers rubber goods	—	1,556,532
Other mechanical rubber goods	—	37,319,249
Hard-rubber goods (except drug sundries):		
Battery jars, boxes, and parts	—	7,012,480
Mouthpieces for pipes, *etc.*	—	401,103
Combs	—	2,261,676
Other hard-rubber goods	—	7,006,142
Druggist sundries (except rubber gloves):		
Water bottles and fountain syringes	610,551 doz.	3,372,875
Nipples and pacifiers	517,281 gross	1,209,716
All others	—	5,717,022
Rubber erasers, except pencil plugs	1,679,373 lbs.	902,231
Rubber bands	4,271,131 "	1,749,292
Rubber gloves:		
Electricians gloves	14,716 doz. pairs	275,862
Surgeons and household gloves	1,185,221 " "	2,172,950
All others	175,127 " "	532,735
Rubber cement	15,417,189 gals.	8,931,113
Rubber flooring (tile or sheet)	8,771,293 sq. ft.	2,661,597
Rubber mats and matting	—	10,624,592
Tire sundries and repair material	—	8,899,832
Camelback	34,126,118 lbs.	7,229,895
Rubber thread	5,618,105 "	3,475,477
Jar rings	6,117,233 gross	1,954,961
Bathing caps	789,501 doz.	1,230,106
Sponge-rubber products	—	9,291,743
Gutta-percha products	—	3,453,443
Other manufactures of rubber	—	35,202,663
Grand Total All Rubber Products		$858,888,117

Methods of Marketing Products

Domestic distribution. The marketing and distribution of rubber products is an undertaking of great magnitude. Enormous advertising expenditures are made to acquaint the general public with rubber products, and vast, nation-wide organizations have been set up for the storage and sale of all commodities. No one form of distribution is used exclusively for any given commodity, inasmuch as most rubber products are related to other industries. For example, the distribution of tires conforms closely to the distribution system originally developed for the automobile industry.

Tires. A first, after supplying the automobile companies with casings and tubes for new cars, a system of branch warehouses and sales offices grew up through which a new class of merchants, known as tire dealers, were supplied with stock. This outlet developed because it became evident that the service necessary in the up-keep of tires was of paramount

importance and that the ordinary merchant or retailer could not supply it effectively. With the development and perfection of the automobile tire, however, the service angle has become somewhat less important, so that at the present time tires and tubes are marketed under about every plan used in merchandising other products.

Some of the forms of distribution used are as follows:

1. Direct sales to automobile companies as original equipment on new cars.
2. Direct sales to large consumers, such as taxicab operating companies, bus lines, public utilities, and other large users of automotive vehicles.
3. Through branch warehouses and sales agencies to retail dealers.
4. Through jobbers to the ordinary type of merchant.
5. Mail-order houses.
6. Chain stores.
7. Department stores.
8. Company-owned and -serviced retail stores.

Rubber boots and shoes. Rubber boots and shoes naturally are marketed in a somewhat similar fashion to leather shoes, using, to a great extent, the outlets already in existence for the distribution of all kinds of footwear. The flow of product is from factory to warehouses, branch warehouses, or jobbers, and then to the retail trade.

Druggists' sundries. Druggists' sundries, including such items as hot water bottles, syringes, rubber gloves, catheters, air pillows, and mattresses, are distributed through the established drug trade channels. In some cases, the goods are handled through jobbers, while in others, as in the case of the chain drug-store trade, the shipments are made from factory to the chain store warehouse for further distribution.

Mechanical goods. The so-called mechanical goods division of the rubber industry is under a decided handicap as to distribution method. A great portion of the mechanical goods production, such as belting and various types of hose, is manufactured to the order or specification of the consumer, while certain styles or stock sizes are handled through the jobbing trade to mill supply houses and thence to consumers. There is a certain volume of business in hose which is supplied on Government specifications through bids for city, county, state and Federal Government departments. The products demanded in this way range from the [illegible]

Rubber flooring. [illegible]

vessels, elevators, private homes, and apartment houses. It is essential that the manufacturer or dealer perform the installation inasmuch as the subsurface must be properly prepared and the rubber tiling should be installed only where physical conditions are conducive to satisfactory service. These essential conditions can only be known to an expert.

Rubberized fabrics. Rubberized fabrics and clothing represent still another form of marketing. Rubberized automobile topping is sold to automobile manufacturers or body builders and to the so-called "retopping" trade, mostly direct to the retopper, but sometimes through automotive jobbers. Rubberized fabrics usually are sold direct to the raincoat manufacturing trade for the fabrication of raincoats and other waterproof garments, although there is some jobber distribution. Still other types of rubberized fabrics are sold to hospital and drug supply houses and department stores for distribution. Some manufacturers of raincoat fabrics also produce rubberized clothing, which makes it necessary for them to provide still another form of distribution to wholesale and retail dealers in rubberized clothing. This distribution might include specialty stores handling this type of clothing only and also department stores.

Rubber heels and soles. There are numerous other rubber commodities handled in a fashion peculiar to the particular product. For example, rubber heels and soles are sold to shoe manufacturers who apply these heels and soles to their shoes in their own factories. Other large outlets for these products are jobbers who sell to the shoe repair trade and direct sales to chain-operated shoe repair shops.

Export of products. Varying policies are pursued by rubber manufacturers in connection with the distribution of their products in foreign countries. Some of the large manufacturers have separate export companies formed to take advantage of price maintenance practices permitted under the Webb-Pomerene Law, while other companies sell direct to foreign distributors or agents.

In the first case the manufacturing company usually sells its product to its export company, which is charged with the full responsibility of foreign marketing. This may be conducted through foreign branch and warehouse organizations, or through native distributors and agents.

Persons Employed in the Industry

According to the Biennial Census of Manufacturers for 1937 there were 129,818 wage earners employed in the 478 establishments of the rubber industry. Of this total 63,290 wage earners were employed in manufacturing tires and tubes, and 18,356 were employed in the manufacture of boots and shoes. The balance are employed in miscellaneous branches of the industry, making rubber heels and soles, rubberized fabrics, rubber sundries, and mechanical rubber products. In that year \$171,305,000 were paid in wages. The value of the articles produced was \$883,033,000.

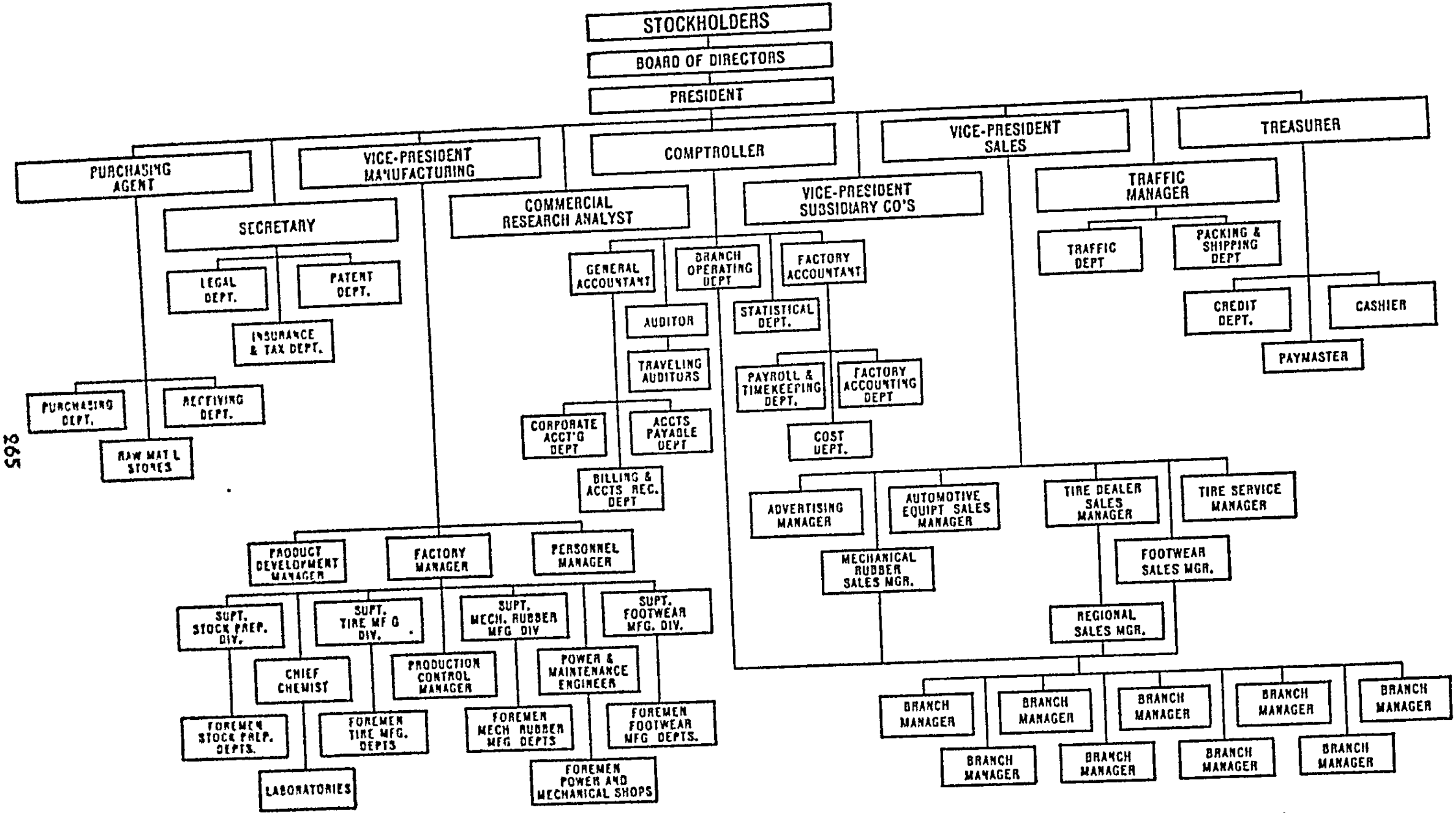


Fig. 2. Organization of a typical rubber company.

Capital Investment in and Methods of Financing the Rubber Manufacturing Industry

Little accurate information exists by which the progressive increase in capital investment in the rubber industry can be traced. It is estimated, however, that the total world-wide investment of American rubber companies amounts to $1,250,000,000. Of this approximately $1,000,000,000 represents stockholders' equity in the form of preferred and common stock and earned and capital surplus, while the bonded debt amounts to approximately $200,000,000.

In recent years the tendency has been toward reducing the funded debt and increasing the capital stock, thereby saving interest charges. This trend began on a large scale during the 1927 and 1929 boom period when many companies reduced their funded debt by the flotation of no par value stock issues with consequent reduction in interest charges. Expansion programs were also financed through stock sales during this same period rather than from accumulated surplus. Since the depth of the depression there has been a tendency to reduce bonded debts out of earnings rather than through flotation of stock.

Economic Significance of the Rubber Industry

Since the development of the rubber industry took place during the era of greatest general industrial progress and expansion, very few people realize its full significance. It is not difficult, however, to appreciate the value of rubber in the personal and industrial life of today, for it is only necessary to visualize conditions if the supply of rubber were to be cut off suddenly through some catastrophe. The fact that over 82 per cent of the rubber consumed in this country is used by the automobile industry is evidence that the economic significance of rubber corresponds to that of the automobile industry.

Most economists recognize the development of the automobile industry as one of the foremost reasons for our recent industrial progress in the United States. The automobile industry in its development helped absorb the labor displaced by the mechanization of other industries, at the same time opening up a wide market for raw materials, machinery, and accessories. It is questionable whether the automobile industry could have developed as it did without rubber. Pneumatic tires made it possible for automobiles to travel over only partially developed roadways, which they could not have done with any other known wheel coverings. Without the comfort secured by the use of pneumatic rubber tires, it is very doubtful whether the tremendous market for automobiles would have developed when and as rapidly as it did. In order to visualize a world without rubber, one need only to have seen the wheels on bicycles and trucks utilized in Germany during and immediately after the First World War. These very unsatisfactory wheels were merely variations of the old-fashioned, metal-tired wagon wheel, some of which were equipped with steel springs. They gave very unsatisfac-

tory performance, depreciating the motor vehicles and roadways at an extremely rapid rate, and would prove decidedly unsatisfactory on pleasure vehicles or passenger busses.

There are a great many other developments in the rubber field which have aided materially in our industrial development, although much less spectacularly than in the automobile industry. The use of rubber belting in power transmission and as a conveying medium, replacing manual methods and more complicated mechanical conveying devices, has aided in reducing the cost of producing innumerable raw materials and manufactured commodities, placing the prices of former luxuries within the reach of all. In the electrical field it is very fortunate that rubber was available in sufficient quantity at the time of this industry's expansion. Rubber undoubtedly assisted greatly in the development of the electrical industry by offering a commodity of highest insulation value which could be used in the innumerable ways that have been developed up to the present time.

The use of rubber in the form of hose undoubtedly has saved millions of dollars of fire losses. Its use in sports, also, although representing a very small percentage of the rubber consumed, has undoubtedly had quite an important bearing in our industrial development, since recreation is so necessary as a safety valve for people working under present-day high-pressure conditions.

In the current year of 1940 the Defense Commission has listed rubber as one of the important strategic materials. As a vital factor in national defense, the industry has welcomed steps that have been taken by our Government to increase stocks promptly in the present emergency. The Rubber-for-Cotton Exchange insured us a reserve stock of approximately 88,000 tons by the end of September of this year and the recent formation of the Rubber Reserve Company, a Government corporation backed by Reconstruction Finance Corporation loan funds and coöperating with the industry, contemplates the acquisition of 333,000 tons additional reserve stock by the end of 1941.

With these reserve supplies reaching us in growing volume and with the industry's capacity to increase production of both synthetic rubber and reclaim, we can look forward with confidence to the industry's ability to supply the needs for domestic and military purposes.

Possible Future Developments

For many years chemists have experimented with the hope of producing a synthetic rubber that would replace nature's product, and although during the First World War Germany did make and utilize synthetic rubber with some success the prohibitive cost and unsatisfactory quality for the ordinary product limited its use. In the last decade so-called synthetic rubbers or rubberlike materials have been developed to a high degree both in this country and in Germany. These materials have qualities that differ from natural rubber, particularly with respect to their oil-resisting qualities, which make them now indispensable in the

manufacture of gasoline hose, fuel-tank-wagon hose, and many other products where contact with oils and grease is involved in their use.

In the current emergency when there is a possibility that our crude rubber supply may be cut off the various new synthetic rubbers are coming into prominence and, although their cost is considerably higher than natural rubber, in an emergency manufacturing facilities could be expanded in this country to manufacture a large part of our rubber requirements from raw materials domestically available.

Both rubber growers and manufacturers are constantly alert for new uses for rubber, although there are more than 30,000 rubber articles now being produced. One of the outstanding new uses which is constantly growing is that of equipping farm vehicles with pneumatic tires. Another is the increased use of rubber in more and more parts for motor vehicles and airplanes. Another development which holds great possibilities is that of the whipped or foam type of sponge rubber, which may ultimately replace steel springs and padding in the upholstery and bedding field.

13

The Leather Industry

Early History of Leather

Early records of leather. The first known authentic records of any civilized stage of existence go back to the time of the building of the Pyramids, nearly 5,000 years ago. From the carved tablets which the Egyptians used then, we have learned much about the history of leather. That the Egyptians and their neighbors valued leather highly is evident from the fact that it was classed with gold, silver, ivory, and rare woods, and was given to kings and gods as tribute. Some articles of leather more than 33 centuries old have been unearthed in tombs and found to be in a perfect state of preservation. An early Arabian formula for the making of leather is as follows:

> The skins are first put into flour and salt for three days, and are cleaned of all the fats and impurities on the inside. The stalks of the chulga plant, being pounded between large stones, are then put into water; applied to the inner side of the skin for one day; and the hair having fallen off, the skin is left for two or three days and the process is completed.

Leather used as armor. Among the ancient Greeks, leather appears in their mythological stories, handed down from generation to generation, by word of mouth, even before the poets put them into written form. Zeus, the great god, is described as wearing what is called the "aegis," a rough hide that covered his head, neck, breast, and left arm, and that is supposed to be the hide of the goat that suckled him. Helmets and shields of leather were worn by Grecian soldiers as far back as the earliest legends. Ovid describes the hero, Ajax, in these words: "Ajax, to shield his ample breast, provides seven lusty bulls, and tans their sturdy hides." The famous legend of the founding of Carthage tells how Queen Dido, when promised only as much land as could be covered by a bull's hide, cut the bull's hide into thin strips and encircled enough land upon which to build the mighty citadel of Carthage.

Other early uses of leather. Leather was used by the Greeks in the building of ships, sails, and houses, as well as for clothing. Much of the importance of leather to the Romans can be assumed from the fact that

it was once used as a basis for money. Our word "pecuniary" comes from the Latin word "*pecus*," meaning "cattle."

Early methods of tanning. The tanneries were placed outside the city walls, and the wet skins were often spread upon the ground for people to walk upon, so as to toughen them. Two classes of labor were employed, tanners and leather cutters; and the latter were considered artisans of the very highest order. The Hebrews were the first to discover the value of oak bark in tanning, and this method was as good as any discovered until the introduction of modern tanning methods in America.

Homer's *Iliad,* written about 1200 B.C., describes what is possibly the oldest form of good tanning, the "Shamoying process." This is the method of opening the pores of the hide by repeated washings and thereafter forcing oil into them by beating and rubbing while the hide is stretched and staked out, the entire process requiring about 2 hours' work. In Rome, as in Egypt and Greece, the tanners were a distinct class of people. The Romans also gave us the word "tan," which comes from "*tanare,*" meaning "oak bark." Roman, Greek, and Pompeian tanners all used limewater to speed up the process of dehairing a hide, the hair being removed with the scraping knife and the beam. For tanning, oak bark was preferred. Hides were soaked in great vats containing oak bark and, sometimes, roots and berries of various kinds. The tanned hides were packed flat with powdered seeds between the layers and left for months, after which they were hung up on poles and later smoothed out with rolling pins—a process discovered by the Hebrews. Most of the workers were slaves, though a few were free men; and one, Clion the Tanner, rose to great political power.

Leather industry of the Middle Ages. The first mention of leather in France recalls the story of Crispin and his brother Crispinianus. Here were two tanners and shoemakers who became martyrs and now are the patron saints of shoemakers. All over the world, but most particularly in Italy, St. Crispin is revered by those engaged in the art of making shoes. France was then Gaul, a province of Rome, and it is considered most likely that the brothers Crispin learned the art of shoemaking from the Romans. It was in the Middle Ages that industry first began to be organized into various trade guilds, or fraternities, usually called "companies" and sometimes "misteries." These guilds were very powerful and ruled the apprentices and members with an iron hand, often even playing an important part in politics. The leatherworkers were among the first to form a guild, or fraternity. In France, the Brotherhood, or Fraternity, of Leather-Workers was established, in 1397, by Charles the Sage and was controlled by the Church. The right to become a tanner was bought from the King at a cost of 16 sous, and each member was sworn to observe the customs and moral precepts of the trade.

Trade guilds. The guilds reached their highest stage of development and their greatest power in London, where entire sections of the city were devoted to the cordwainers', or leatherworkers', ward. Each guild came to enjoy special rights and privileges, and to create monopolies by

royal charters. Among the first five so organized were the saddlers, skinners, goldsmiths, tailors, and mercers, or dealers in textiles. At that time, the saddlers' guild was—and it continued to be—one of the most influential of all; it had its own guildhall, one of the first to be erected. Of 111 different trades listed in London in 1422, 11 were leather trades.

The Leather Industry in the United States

Early history of leather in America. When America was discovered, it was found that the Indians were well versed in the art of tanning and had many uses for leather. It is not possible to find out how they acquired this knowledge; nor is it known when leather first made its appearance on this continent. While they made a fairly satisfactory kind of leather, the Indians knew nothing of the superior method of bark tanning; they had, however, perfected a process for dressing soft leathers—the famous buckskin tan—which they taught to the white settlers and which has scarcely been improved upon even today. Leather treated by this process has never been surpassed for softness and pliability or for its ability to keep out water.

Methods of tanning. The Navajo Indians were especially remarkable for their skill in dressing the hide and later ornamentating it, but the Crow Indians were generally considered the most skillful in their tanning methods

The work of skin-dressing was largely, if not entirely, performed by the women of the tribe. The skins were collected and heaped up in piles, wetted and allowed to decompose until the hair was loosened. Then the radius of the large foreleg of the reindeer was cleaned of its flesh and one side of the shaft, or central bone, was removed, leaving two sharp edges. One side was rounded and dulled, the other sharpened. Each skin was then placed on a beam of wood, usually the trunk of a tree, and scraped with this reindeer-bone implement, the motion being against the hair and away from the body of the worker. For the flesh side of the hide, a different implement was used. This was made from the heel bone of the reindeer, cut obliquely so that the flat edge formed a blade, which was sharpened and serrated. This tool became a chisel and adz combined and was firmly held in the hand by the aid of a strap, or thong, tied around the heel bone of the reindeer and under the wrist of the worker. After being scraped on both sides, the skin was rubbed with a mixture composed of the brain and the liver of the animal and later subjected to a thorough rubbing similar to that employed in the laundering of clothes.

With the Crow Indians, the method was to immerse the skins in a solution from the ashes of the campfires. After scraping and dehairing, the skins were stretched out upon the ground or upon frames to dry. They were then rubbed with the brains of the buffalo or elk, which were worked into the substance of the skin by manipulating the skin by hand. The final process among the Crows was that of smoking. A small hole was dug in the ground, and in this was made a fire of rotten wood, so that

there might be much smoke with little blaze. Around this hole, poles were erected and covered with skins to form a tent. The skins to be cured were placed within this tent, the flaps of the tent carefully sewed up and left for several days, until all the skins within had been thoroughly impregnated with the smoke. The leather thus made would withstand any amount of wetting and, when dry, would return to its original soft and pliable condition.

Shoemaking in the colonies. Where the first tanning was done by white men in this country is still a question. But we do know that Experience Miller, a tanner, came to Plymouth on the good ship *Ann* in 1623, and he may have tanned leather before the settlers at Jamestown, Virginia, who came to America several years previously. It does not appear that shoes were made in this country until 1628. It was in the latter year that two shoemakers, Thomas Beard and Isack Rickman, came from England, in order to supply settlers with shoes. Up to this time, settlers had brought their shoes from England or worn moccasins, which they learned to make from the Indians. These two shoemakers were an importation of the Plymouth Company, for it is known that they were to receive "their dyett and house room at the charge of the companie"; and it is also recorded of Beard that he had in the ship "divers Hydes, both for sole and upp leathers, he intends to make upp in boots and shoes."

Tanning process used in the colonies. Up to the latter part of the eighteenth century, no one had looked upon tanning as a scientific process. It was a method of preserving hides, of keeping them from rotting, and of making them pliable—no more. The methods of the ancient Hebrews were continued with little variation and addition down to this time, and each tanner made leather as best he knew by a sort of rule-of-thumb process. Boxes made of plank were sunk in the ground for vats. Oak bark was then almost the only tanning agent used; this was crushed by rolling heavy stones over it. The hides were soaked and scraped, the hair being loosened by soaking them in a bath of lime and water. The method of tanning was to sprinkle the bottom of the vat with fine bark and to lay a skin or hide upon it. Another layer of bark was sprinkled over this and another hide laid on the top of that, and so on, to the depth of the vat. Water was poured over all, and the hides were allowed to rest in this solution for a period of 6 months or more, although they might be repacked during that period. Heavier hides were allowed a longer time.

Contributions of Sir Humphrey Davy to the leather industry. Sir Humphrey Davy, famed more for his researches in other directions than in leather, made a highly important contribution to the tanning process when, about 1800, he examined vegetable products other than oak in order to increase the available supply of tannin in the world. In addition to the bark of the oak tree, the leaves of the sumac and growths known as "nut galls" had been used in tanning at various times, together with certain Oriental vegetable growths that were not readily available at the points of tanning. To these, Sir Humphrey Davy added the bark

of the hemlock and of the mimosa trees, the wood of the quebracho, the oak, and the chestnut trees, and the fruit of the divi-divi, valonia, and myrobalans. Although undertaken for English tanners, Sir Humphrey Davy's efforts were more vital to America than to England, for the reason that hemlock grew in vast profusion in the United States.

Discovery of chrome tanning. Nearly a century passed before an American chemist named Schultz made a discovery of as great importance as the researches of Davy. He was seeking a means to prevent the white-alum tanned leather, then used for corset-stay covering, from turning brown.

Through experimenting with different chemicals that might accomplish his object, Schultz found that cromium salts, acting on hide substance, made a leather different from any previously known. Though the action of these salts had been studied somewhat in England many years earlier, it remained for Schultz to make chrome tanning a commercial possibility. Even then tanners laughed when they saw the leather produced from his process, for at first it was stiff, hard, and blue in color, instead of mellow and red as was vegetable-tanned leather. A young Philadelphian named Robert Foerderer, after long and patient experimenting, finally perfected the new process and began to produce this new type of leather. He learned how to treat it with soap and oil —to "fat-liquor" it, as the process is known. This operation, which is very necessary in modern chrome tanning, is only a modification of the old Indian method of softening deerskin by dressing it with fat. Foerderer became a very successful tanner. His product took the place of the heavy bark-tanned leather, such as the cowhide leather of which grandfather's boots were made. Through his enterprise and that of Schultz, the chrome process of tanning became firmly established

Introduction of machinery. Between the time of Davy's great work and the development of this new process of tanning, American inventive genius made an important contribution to the tanning industry that was destined to revolutionize the methods of the world in a manner not seen since the days of Simon at Joppa. This was the introduction of machinery to take the place of hand labor in the crushing of bark and in certain finishing processes. The splitting of leather was then unknown. Hides were taken from the vats after about 6 months, when half tanned, rubbed with a thick stick over a beam, and shaved down to the desired thickness Not only were the shavings but the workmen's time also was wasted, since one workman could shave but four hides a day. Sole leather was finished by rolling a smooth grindstone over it.

In 1809, a patent was granted to Samuel Parker of Newburyport, Massachusetts, for a machine that would split leather to any thickness, each one of the splits being available for certain uses. These two splits were called the "flesh split" and the "grain split," according to the side of the leather that was used. Thus the output of usable leather was at once doubled, and it became possible for one workman to split several hides a day. Still, the important parts of the work—the cleaning, fleshing, and dehairing of the hides—were laboriously performed by hand,

and for many years, ingenious and inventive minds sought a solution by means of machinery.

The first experiments with a machine to accomplish this purpose were conducted by moving the skin against a fixed knife. In the further development of this machine, the next step was to move the knife against a skin that was fixed. It remained for Mellen Bray, a Maine tanner, to solve the problem in 1850, when he invented a machine combining both of these principles. His machine consisted of a table on which the skin was held and moved against the knife, while the knife was fixed to a cylinder and moved against the skin. The first shoe-pegging machine was operated by Charles D. Bigelow, in 1852, at his shop in Jacob Street in "The Swamp" district of New York. From testimony in a lawsuit against infringers, we learn that "it would peg around a large size man's brogan in one minute, and the work was done much better than by hand, both as regards uniformity and firmness."

It was America's contribution to the leather industry—the introduction of machinery—which revolutionized the method and equipment of tanneries all over the world. Europe was compelled to acknowledge her indebtedness to us and either to adopt our methods by installing our machinery or to be outdistanced in the race for supremacy in the industry.

Growth of the leather industry. In 1849, there were 6,686 tanneries in operation in this country, a figure that has since been exceeded but once. This figure was the result of the great development of hemlock tanning, by which it was possible and profitable to establish a tannery of reasonable size close to any tracts of hemlock forest land. In the 50 years that followed, after a slight temporary increase, the number of tanneries declined, until, at the close of the century, there were but 1,306 in operation.

The gradual introduction of machinery is one of the prime causes for this change, since it became more economical to build larger plants capable of greater individual production than to continue to operate the smaller plants after they became obsolete. The development of the railroads was another contributing cause, since, with the improvement in transportation, it no longer became necessary for the tannery to follow the forest to obtain the bark. Whereas it had been more economical in the early days to carry the lighter hides to the tannery, rather than the heavier bark, it presently became more feasible to transport the bark over reasonable distances to more fully equipped tanneries.

These 6,686 plants that were in operation in 1849 employed 25,595 people, while the 1,306 that were reported by the Census of 1899 gave employment to more than double that number, or 52,109. But the wages paid had trebled during the same period. The total wages paid by the 6,689 plants in 1849 were $6,541,678, and 50 years later twice as many employees received $22,591,091. These plants had increased their consumption of raw material six times in value to obtain a finished product that was valued about four and a half times greater. This means that the raw material used was valued at $155,000,004 in 1899, as against

$26,429,881 in 1849; while the finished product in 1899 was worth $204,-038,127, as against $43,457,898 in 1849.

According to recent statistics furnished by the Census Bureau, there are approximately 400 establishments that do tanning of one kind or another and employ upwards of 50,000 people. It is estimated that, in 1937, the total wages paid approximated $61,000,000.

Packing industry's influence on leather production. The great packing industry of Chicago and the West which, in 1919, showed receipts of about 10,000,000 head of cattle, wrought vast changes in the leather industry. During the first half of the last century, the West was, to all intents and purposes, an Indian-settled wilderness. What are today the great cattle ranges were then hunting grounds for the red men, producing nothing that was of value to the leather or to any other industry. Hides were eagerly sought in all parts of the world, and our hide buyers were compelled to make long journeys by ship to procure them.

Influence of the Gold Rush on the leather industry. An important spur to the tanning industry at the opening of the period we are now considering was the discovery of gold in California and the historic rush of gold seekers to a new territory that provided a new source for tanning material. This source was the California tanbark oak. There was an increased demand for leather by the army of miners who sought gold. To supply that demand, tanneries, utilizing the bark of this tree, were established within the new state. In 1852, one tannery located in Sonoma County was producing leather to the value of $30,000 a year; 4 years later, there were 18 tanneries operating in the state, with an invested capital of $94,000. About 1850, the merits of "union leather"—which is a combination of oak and hemlock tannages—began to be generally recognized, and its development thereafter was rapid and great. It was found then that this method of tanning produced a leather peculiarly suitable for specific purposes where a mild, mellow leather was required. After 1850, the production of union leather increased to such an extent that, in 1878, there were 800,000 union-tanned backs cut up in Massachusetts alone and the use of this leather had become universal in this country.

Location of tanning centers. The making of leather from cattle hides is one of America's stable industries and one of its largest. Great changes have occurred in the methods followed by our tanners today as compared with the days when Experience Miller came to Plymouth in the good ship *Ann*. New York early became the center of the tanning industry, and the first leather center was located in what was, and still is, known as "The Swamp," or that part of lower New York where Brooklyn Bridge rises to span the East River. The tanners making hemlock leather located along the line of growth of that stately forest tree which took them through Pennsylvania, lower New York, Michigan, and northern Wisconsin. Those requiring oak bark followed a line through the mountains of Pennsylvania, Virginia, West Virginia, North Carolina, and Tennessee. The big tanneries of today are still found to exist in these broad geographical areas. Pennsylvania is our largest

tanning state, owing to its forest growth of both oak and hemlock, as well as an important producer of goatskin upper leather. Wisconsin, today, yields the most hemlock bark and has become another center of tanning. The industry also has grown apace in the Southern states, where not only the oak abounds but the chestnut tree as well, the wood of which, because of the tannin it contains, has become of great importance to sole-leather tanners.

The largest merchandising centers for heavy leather are Boston, New York, Philadelphia, Cincinnati, Chicago, and St. Louis. San Francisco also is an active leather mart for the merchandising of California tannages and for export to the Orient, where a constant demand exists for American leather.

Raw Materials of the Leather Industry

Supply and demand of hides. The hide supply depends upon the number of animals killed for meat. In this country, our requirements for hides for leather are greatly in excess of the number of hides taken off by all the killers of cattle in the meat industry. Therefore, to supply our tanners, we must go to countries where the kill of cattle for meat supplies an excess of hides for the local tanning industry. Take the Argentine, for example, where vast packing houses operate to export meat to European countries but where the population is too small to require all the hides that are produced and where tanning is not a highly developed industry. Our United States tanners require approximately 19,000,000 cattle hides per year (exclusive of about 3,000,000 kips used for side leather). Since we normally produce about 16,000,000 of these, we must import about 3,000,000 additional hides. Of these 19,000,000 hides, roughly 10,500,000 go to the makers of shoe uppers, who split the leather, thereby making it thinner. The balance of 8,500,000 hides go to the tanners of sole leather and leather for machinery belting, and a small portion goes into the making of upholstery, automobile, bag, case, strap, harness, and other miscellaneous leathers.

Curing pelts. The pelts of animals, usually those killed for food, come to the tanner in three different conditions: green-salted, dry, and dry-salted. A green-salted hide is one which has been kept from decaying by an application of salt. In the large slaughterhouses, the fresh hides, as removed from the animals, are carefully spread out, one on top of another, flesh side up, with layers of salt between, in beds or packs, where they remain 30 days or more to cure. In this way, the hides are kept moist and sound until they are ready to be bundled and shipped to the tanner. Dry hides, as the name implies, are those which have been exposed to the air and sun until they have become bone-dry. They usually are stretched out flat during the drying process. Dry-salted hides are similarly treated, but salt is applied to them before they are dried. Because dry or dry-salted hides are liable to damage during the drying, green-salted hides are usually much superior and constitute by far the largest number of the hides used by the tanners

Differences in pelts. Leather originates from three classifications of pelts: hides, kips, and skins. Hides come from the mature animals, such as full-grown cattle. These make a heavy leather, thick and strong, and stiff or soft, as the need requires. For the most part, they go into the making of shoe soles and heels and machinery belting; when split, they are used for shoe uppers, bag, case, strap, automobile, and upholstery leathers. Kips come from veal animals, classified as to weight, and are tanned mostly for shoe uppers. Skins are obtained from smaller animals, such as calves, sheep, goats, kangaroos, and so forth, and go into the making of shoe uppers, pocketbooks, bookbinding materials, gloves, and fancy leathers. It is not proper to speak of "cowskin" or "goathide." Hides refer to the heavier type of pelt from steers, cows, and bulls.

These raw materials for the tanner are principally by-products of other industries, particularly of the meat industry; although, in the case of sheepskins, the primary product may be wool and, in the case of goatskins, the product for which the animals are raised may be milk. Some animals or reptiles are killed solely for their skins, but such skins represent a very small fraction of the total amount of leather tanned. Snakes, lizards, walrus, hair seals, and alligators are, to a considerable extent, primarily killed for their skins. Rarely, if ever, however, are the animals that supply us with our important hides and skins killed for such a purpose. Cattle are not raised for the hides they produce. Man requires meat for food, and, as a result, the hides or skins are a by-product of the meat industry. The supply of cattle hides is dependent on the supply and demand for beef at the big packing centers.

Classification of hides. Many classifications are made of hides, but we need consider only the most important of these. The best imported hides are those from South America, called "*frigorificos*" because they come from the freezing plants of the South American packers. These compare favorably with the best hides produced in this country. We also import "saladeros," the hide from the South American city abattoirs; "mataderos," the country hide of our southern neighbors; and other typically named hides too numerous to mention. The important classifications in this country are the "packer hide" and the "country hide."

Packer hides preferred. Packer hides are produced by the larger meat-packing houses in the West, with headquarters in Chicago. Country hides come from the small butchers and farmers and are collected by hide dealers. Because of the opportunity afforded by large-scale production for highly specialized workmanship, the skinning or "flaying," curing, and grading of the hides are usually much more expertly and satisfactorily done in the large packing plants than in the small. The superiority of big packer hides is sufficiently great so that they bring a higher price in the market than do small packer, or country, hides; and they are more in demand by tanners, to whom condition, grade, pattern, and the opportunity of purchasing any of several standard selections in carload lots are of serious importance. Country hides and skins are removed by farmers, ranchmen, and local butchers, or by their helpers,

who generally are inexperienced in skinning. This classification includes "fallen" hides, or those from animals that have died from disease, accidents, or natural causes, as well as those from animals that have been slaughtered for food. Country hides originate in small numbers, in scattered and remote sections of the country, and seldom are treated in a careful and efficient manner with respect to skinning, curing, and marketing. The result frequently is a poor product of irregular pattern and trim, with many imperfections. In normal years, hides produced in this country are about 75 per cent packer and 25 per cent country. Some hides, both packer and country, have a lower value due to tick or grub damage or branding.

Damage from ticks and grubs. A tick stings the animal, raising a welt, which leaves a wound and makes the finished leather spotty in appearance, although it does not affect its wearing qualities. A grub is a worm, which, growing from an egg laid by a fly on the hair of the lower leg of the animal, bores into the flesh and works its way inside to the animal's back, where it makes a hole through the hide, through which it emerges and falls to the ground. There, after time and change, it again becomes a fly, ready to lay more eggs and repeat the cycle. The holes made by the grub in the hide are about one eighth of an inch in diameter and are found in hides in all months of the year, with the larger percentage of grubby hides being produced during the months from December to July, inclusive.

Sometimes there are so many grub holes found in a hide that it is referred to as a "pepperbox," and the damage to its value for any use is obvious. Concerted action by cattle owners in killing the grubs before they emerge from the cattle (and several well-known and effective means for doing this are known) would effect a great economic saving. The tick is found only in some of our Southern states, and it is being eradicated in an effectual way by the establishment of "dipping stations," where affected cattle are submerged in an antiseptic bath. An animal given care and kept clean in healthful surroundings is not so likely to be annoyed by these pests.

Damages from branding. Branding of cattle results in a handicap to the seller of the hide. The cattle raiser, in order to identify his calves, applies a hot iron to the hide of the animal, sometimes on its rump and at other times on its sides. In some cases, both sides of the calf are branded. These brands are of varying types, ranging from a small letter several inches high to a great design or series of initials of 2 feet square. It is a practice which causes the loss of many thousands of dollars worth of leather yearly. Where the brand is applied, the hide is seared so that the fibrous structure of the hide is destroyed. This branded part will not make a normal piece of leather. The custom of branding cattle is slowly decreasing in this country, owing to the fact that Western ranges are more and more being taken over for cultivation and the herds, consequently, are becoming more nearly domestic farm stock, being confined within fences where they cannot become mixed with other herds. There still exists, however, a considerable yearly waste

attributable to this so-called "necessary" practice of the cattlemen. If the practice of branding must continue, tanners recommend that brand marks should be placed on the cheek, neck, or shoulder, and not on the *body portion of the hides.*

Geographical Source of Pelts

Sources of hides and skins. North and South America, countries with vast grazing lands, naturally raise the cattle herds that supply us with beef and veal. The United States, from its Western states, sends the largest quantity of cattle to the main Midwestern packing centers. The Argentine, with its miles of pampas, raises great herds of cattle that go far in supplying England and other European countries with food. It is from these two sources that the tanner obtains most of his cattle hides and calfskins. But the American tanner also imports hides and skins from other South American and Central American countries and, to a limited extent, from Europe, Australia, Africa, and China, depending on world market conditions. Countries where the tanning industry is developed and where the population requires all the heavy leather that can be made are not exporters of hides. On the other hand, such countries not only tan all hides produced but, like the United States, have to go into the world markets for a part of their raw material.

The skins of sheep, goat, pig, deer or buck, ostrich, snake, lizard, alligator, shark, seal, and walrus, as well as horse and buffalo hides, all are of considerable importance. Sheepskins and lambskins of many varieties are used in making leather, the total number tanned each year in the United States being actually greater than the number of cattle hides tanned; although, because of the relatively low value of this type of leather per skin, the total value of annual production amounts to only 12 or 13 per cent of that of cattle-hide leather.

The sheep has perhaps the most extended range of all domestic animals, Japan being the only country in the world where it does not live. From the Falkland and Faroe Islands, in the Far North from the Magellanic Territory of Chile in the Far South, the Red Sea area in the Levant, from the arid regions of northern Africa, from nearly all parts of North America, except extreme northern Canada, and from Australia, Europe, Asia, and southern Africa—with the exception of damp, tropical areas—from all these sources, sheepskins flow into the world trade.

Sources of Tanning Materials

Tanning materials. Barks, woods, nuts, and leaves are selected as tanning material in proportion to the quantity of active tanning substance (tannic acid) they contain, to their availability, and to the quality of leather they will produce.

The gathering of oak and hemlock bark in this country is still an industry of considerable size, and it has been greatly developed by increased demands of the tanner. By careful analysis, it has been found

that many other vegetable growths contain the proper acids for tanning comparable in every way with oak and hemlock liquors. The principal tanning material used in this country, in addition to oak and hemlock bark, is chestnut wood, found in great profusion in our Southern forests. This wood grows upon the mountainsides, is cut into logs, and is then brought to the grinding mill. Here it is ground by powerful chipping mills to what resembles coffee beans. In this form, it enters the leaches, where the tannic acid is extracted from the wood, goes through several purifying processes, is evaporated, and is sold to the tanner either as a powder or in concentrated form. The chestnut is one of America's most beautiful trees.

Tanning material imported. With all our vast areas of woodland of chestnut, oak, and hemlock, however, we must import great quantities of tanning material, the most important of which is quebracho. This remarkable tree grows in Argentina and Paraguay. Its name is derived from the Spanish words "*quebrar,*" to break, and "*hacha,*" axe, or "axe-breaker." It has earned this name because of its flinty hardness. It is shipped by rail or barge hundreds of miles from its stands in the great forests of South America to the grinding stations and extract works near the seaboard. Here it is prepared for extracting (as is chestnut in this country) and leached, and the extract is shipped to this country in concentrated form. We import some quebracho in logs, and the extracting is done here, but this is not the prevailing custom. As a tanning agent, quebracho is generally used in connection with oak or hemlock; it is rarely used alone.

Valonia, which is the acorn cup of the Turkish oak, grows generally throughout Asia Minor and is shipped from Smyrna. Mangrove is derived from the bark of the mangrove tree, which grows in practically all tropical island districts. This material, mixed with other barks and extracts, is widely used in the tanning of sole leather. Its increased use is somewhat retarded by the difficulty found in collecting the bark. Galls on the oak tree's leaves are caused by insects which lay their eggs on the leaf or bud and so produce an abnormal growth. This gall nut, when dried, contains a high percentage of tannic acid.

Other tanning agents. Sicilian sumac is considered the best of this variety of tanning material, although good grades of sumac are found in some South American countries and in Virginia. The leaves are collected and dried, then ground to a powder and shipped to the tannery for leaching. Sumac is used to produce light-colored, soft leathers.

Gambier is derived from a climbing shrub found in the Netherlands East Indies; it is also grown in China to some extent. Only the leaves of the plant are used. These are chopped and boiled; the heavy extract is then drawn off in almost a pasty condition, allowed to cool, and cut into cubes, in which form it is shipped. Gambier produces a soft leather and is much used in the production of glove leathers.

Myrobalans are obtained from the unripe, prunelike fruit of a tree growing in India; they contain a high percentage of tannic acid, which is invariably used with other extracts as a tanning material in making

sole leather or leather for machinery belting. Divi-divi is obtained from the dried pods of a tree natural to Central America; this extract, used in conjunction with extracts from other sources, is considered very desirable in the making of sole leather. Wattlebark is from various species of acacia, its principal points of shipment being in South Africa; its use is increasing on account of its high percentage of tannic acid. Palmetto roots also yield valuable tannic acid used in making soft leathers.

Mineral tanning agents. Chromite, the mineral ore from which salts used in chrome tanning are made, is found in the Western states of this country, but most of this material used here is imported from out-of-the-way corners of the world. British and Portuguese Africa supply most of our chromite, and Greece, Cuba, Brazil, and French Oceania provide us with quantities greater than we produce in the United States.

The Manufacture of Leather

Introduction of leaching. The period commencing with 1850 also saw the beginning of the more general introduction of "leaching" into tanning methods. As before, the tanning material was reduced to small pieces; but it was then put into large tanks, where hot water was percolated through it, and thus a liquor relatively strong in tannins was obtained. This strong liquor was used in the tanning vats instead of plain water and aided the tanner to make better leather in less time.

Preparation for the tanning process. The first stage in the preparation of the hide for the actual tanning operation is to cleanse it thoroughly and to bring it back to the soft, pliable condition which it had as a part of the living animal. To do this, the hide is soaked for several days in water in rectangular pits called "soaks," the water being changed occasionally. When the hides are removed from the soaks, they are ready for the removal of the hair, which is the next preparatory step.

Removing hair. The old-fashioned method to remove hair was to sweat the hide, setting up a slow decomposition on its surface, which loosened the hair and made it fairly easy to remove by hand with a blunt knife. The modern and surer method is through "liming," followed by dehairing in a specially constructed machine. The hide is placed in a strong milk of lime and frequently worked, or agitated, and lime is added as the solution weakens. According to the texture and thickness of the hides and to the kind of leather to be made, the time of liming may vary from 3 to 9 days. The liming not only loosens the hair but also tends to swell the hide and to make it temporarily more porous and more susceptible to the action of the tanning liquids. At the proper time, in the opinion of the tanner, the hide is removed from the liming solution, washed, and then placed in the dehairing machine. The hide rolls through this machine in much the same way as clothes do through a wringer, and as it comes out through the rolls, it has had all the hair removed and is clean and light gray in color.

The utilization of hair. The hair thus obtained becomes a valuable

by-product. It is dried, cleaned, and sorted; the coarser mixed qualities are then largely used as a binder in plaster, while the finer ones go into the making of hair felts, carpets, blankets, and many other textiles, some of beautiful appearance and of great value. One interesting use of this material is in wadding for shotgun shells.

√ **Removing surplus flesh.** The next step is to remove from the inner side of the hide the surplus flesh so that the "flesh" side of the hide becomes nearly as smooth and clean as the "grain" side from which the hair has just been removed. The "fleshings" coming from the fleshing machine or from the hand process are used in the making of glue. The glue industry in this country is a large one, and many are the uses of this tannery by-product.

√ **Edible gelatine.** One of our purest and most digestible foods is also made from fleshings. Portions of the skin not suited for tanning, such as the ears, are trimmed off and thoroughly cleaned, limed, dehaired, washed, and sterilized. During the liming, a portion of the hide substance is converted to a substance that is soluble in very hot water. The purified hide material is extracted with steam and water and, when filtered and evaporated to a thick syrup, is the gelatine of commerce. The syrupy gelatine, sparkling clear, is chilled in a refrigerating machine and is then dried in pure air, out of contact with all dust and dirt. Finally, the hardened gelatine is ground up, so that it can be packed. Immaculate cleanliness exists throughout the gelatine plant, the final product being in a class with other modern foods, in that it is not touched by hand from the start of the process until it reaches the consumer.

The tanning process. The notable characteristic of all hides and skins, however, is not so much chemical composition as physical structure. They all are made up of a vast number of minute fibers, intricately interlaced. This structure gives the hide its wonderful flexibility and strength, while leaving it sufficiently porous so that it can breathe, permitting air and moisture to pass in and out through it. The problem of every tanner is to retain this marvelous fibrous texture of the hide, with its strength and flexibility and power to breathe, and yet to make the tanned hide so permanent that the leather will not rot or dissolve or materially alter under normal conditions of use. The tanner has found several ways of doing this, and the description following is of one of the oldest and most-used processes.

The hides, prepared for tanning as described above, may be carried through the tanning process as whole hides, but usually they are cut down the back, making two sides, in which form they go through the tanning operation. The first contact of the hide with tanning liquor occurs in the rockers.

The rockers. A rocker section consists of a series of vats about 8 feet long, 6 feet wide, and 5½ feet deep, arranged so that the tanning liquor, whether it be oak bark, hemlock, or a union of the two, or whether it perhaps contains a proportion of quebracho or one of the other extracts, comes from the bottom of one vat and overflows into the top of the next. The "head," or top vat, contains the strongest solution of

the tannin; and as it gradually makes its way through the vats, it becomes weakened by the presence of the hides. It finally reaches the "tail," or last vat, and then flows to waste, or part of it is recovered and used over again. The hides suspended on the frames of the rockers are moved slowly up and down; this movement serves the double purpose of agitating the liquor and producing an even absorption in the hide, which makes an even color over the entire side of the leather. Much care is necessary in this operation as, practically, the quality of the leather is determined by the attention the hides are given while they are in the rockers. It usually takes about 15 days to plump the hides properly in the rockers and to tan the grain sufficiently to withstand the stronger liquors with which it will next come in contact.

Lay-away vats. After the rockers, the hides are placed in the lay-away vats, which are much larger than the rockers, each hide being laid out flat and sprinkled over with ground bark. The liquor solution is then pumped in until the vat is full, and the hides are allowed to remain there undisturbed for a period that varies with the kind of hides and the nature of leather being produced. The hides are changed in these lay-away vats generally about five times, and each time they are placed in a new solution; so that the entire operation, from the time the side enters the rockers until it leaves the lay-away vats, may be a minimum of 2 months and possibly as much as 6 months.

The hide becomes leather. When the tanning is completed by these processes, or when the sides show that the tanning liquors have taken effect through the entire thickness of the hides in a uniform manner, they are removed and thoroughly washed in warm water to clean off all sediment. After being rinsed thoroughly, they are swabbed with oil, usually a cod oil or a mixture of this and mineral oil. They are then attached to sticks and hung in the drying loft. This drying loft is generally darkened, and a good circulation of air is provided with a certain amount of moisture, so that the drying process is not too quick. If leather dries too quickly, it is likely to become too brittle on the grain side; if it dries too slowly, it is liable to mold. Great care must be taken in this operation.

The subsequent treatment given the leather depends upon the use to which the finished product is to be put. For instance, if the leather is to be used for the soles of shoes, it is put, while still moist, under a brass roll, which presses down hard on the leather as it rolls over it and so compresses the leather, making it firm and solid and at the same time giving it a smooth and polished surface.

If, on the other hand, the leather is to be used for harness or transmission belting, it is put, while moist, together with a considerable percentage of grease, such as tallow, into a very large barrel-shaped drum. This drum is warm inside and revolves on a central axis, whereby the leather is tumbled over and over in intimate contact with the grease, until the grease has all been worked into the leather and some of the water has been worked out. When the leather has been taken from the drum, it is carefully smoothed out by machine, so as to be smooth and flat and free from wrinkles. It is then dried. The extra grease thus put into the leather

adds much to its strength, often as much as 25 per cent, and, in addition, makes the leather more pliable—qualities that are particularly desirable in leather to be used for the purpose mentioned.

Belting-leather requirements. Various modifications are made in the tanning process, as described, in order to make certain kinds of sole and belting leather. In the case of belting leather, the hides must be carefully selected so as to have no imperfections, such as brands, grub holes, or tick marks. The leather should have a good driving surface, so that the belt will not slip on the pulley. It should have a certain amount of stiffness to prevent the belt from curling at the edges and twisting or waving. It should be pliable to enable the belt to hug the pulley. It should have a high tensile strength so as to carry a heavy load without breaking. It should have very little stretch but considerable elasticity, so that it will easily take up and let go its load as it travels around the pulley. It should be straight, so that it will run true on the pulley. It should resist external conditions—such as heat, moisture, and chemicals—so that it may do its work in an enduring way.

Leather for soles. Leather tanned for the soles of shoes may be of very many descriptions. If tanned with hemlock bark, it is made hard and is used in shoes that meet rough usage. Again, it might be an oak-tanned heavy piece of leather for the soles of men's shoes or for shoe repairing, which will give long wear and still be light and somewhat pliable; or it may become a piece of leather for the very finest turned shoes worn by women, where the leather must be so pliable that the shoe can be turned inside out in its making.

We have seen, therefore, that the finishing process, which has taken anywhere from 3 to perhaps 8 or 9 months, leaves the leather in the shape of sides having approximately half of the original area of the untanned hide because of cutting along the middle of the back. The side may be sold, as it is, to the shoe manufacturer, who will use every part of it in the making of his shoes; or it may be sold as a back, which is a side with head, shanks, and belly removed. The leather may be cut to small dimensions by the tanners and sold as strips or blocks, a strip being about 8¼ inches wide by 2 to 2½ feet long, and a block about 12½ by 8¼ inches. Leather in the form of strips and blocks is mostly used by repairmen or sold through hardware and general stores to those who repair their own shoes. The tanner, in many instances, will sell his leather as backs and sides to the sole cutter, who, in turn, will sell to the shoe manufacturer in the shape of outsoles, insoles, counters, heels, and box toes, uniformly graded for quality and thickness.

Bag and strap leather. Luggage leather is bark-tanned, a process similar to that followed in sole-leather tanning except that different tannins are used to make the leather softer than ordinary sole leather. Toughness, to withstand wear, and fine appearance are sought as essential qualities in leathers made for bags and cases. To this end, special care is taken in the selection of the hides and skins tanned. Cattle hide is by far the most important luggage leather. Largely because of their appearance, however, other types of leather are tanned for this service. The skins

of calf, pig, boar, seal, walrus, shark, and ostrich, as well as elk, buffalo, and alligator hides, are used to some extent. Sheepskin is often employed for linings.

Upholstery leather. Although upholstery and decorative leathers of rare beauty were made and used by the Moors hundreds of years ago, it was not until after the development of the modern splitting machine that leather upholstery as we know it today came into existence.

The cattle hides used today for upholstery leather have to be selected with care in the markets of the entire world, in order that the hides be large enough and perfect. Some of those tanned are as much as 80 square feet in area. In the finishing of the leather, which is usually vegetable-tanned, three processes are followed: japanning, lacquering, or a combination of the two.

Chrome tanning. While most of the leather for shoe soles, upholstery, belting, and luggage is made with vegetable tannage, leathers for such important uses as the uppers of shoes are made almost entirely with a chrome tannage. Approximately one half of the leather made in this country now is chrome-tanned, including nearly all glove leather and most fancy leather. Where a blending of the qualities of chrome leather and vegetable-tanned leather is found desirable, as for certain types of belting, a combination of the two processes is used. The skins or split hides are prepared for chrome tanning much as they would be for vegetable tanning, but before they are converted to leather they are swashed about in drum-shaped wooden containers in a solution of common salt or another similar material called a "pickle." This process opens up the pores, so that, when the chrome solution is run into the drum, it penetrates the hide substance rapidly and completely. While months are required to vegetable-tan leather, the time required for chrome tanning is much less—not over 5 or 6 hours being required to make lightweight leathers.

Side-upper leather. Uppers for shoes are made principally from cowhide or from calfskin. The cowhide is cut in two pieces down the middle of the back; and these pieces are called "sides." The sides are then split into two or more layers, in order to make the leather of the proper thickness for use. This leather, made from cowhide sides so split for the upper parts of shoes, is called "side-upper leather." The splitting may occur at any one of several points in the process, depending upon the weight of the hide and the quality of leather being produced. For instance, it may follow the liming, pickling, or chrome drumming. When calfskin is being processed, no splitting is necessary because leather of the proper weight is made directly from the original skin, with only a slight shaving operation at points where it is somewhat heavy and uneven.

Grain and leather splits. The piece of leather that was originally next to the flesh of the animal is called a "split," as is any cut except the outer piece of leather, or hair side, which is called the "grain," or "grain leather." From the grain, the finest side-upper stock of cattle hide is made. The split is sometimes used to make lower grades of side upper;

sometimes it is finished into leather for gloves, shoe tongues, innersoles for shoes, or into leather upholstery or bag leather of medium quality.

It is necessary to put life-sustaining oils and fats back into the hide substance to take the place of the natural animal oils that have been removed in tanning. The sides are again placed in the revolving drums, where they are whipped about in a solution of water, soap, and oil, known as a "fat liquor." Neat's-foot and cod oils, tallow, stearine—a waxlike fat—and ordinary soap are used. These materials thoroughly penetrate the hide substance, being absorbed by each tiny fiber.

Sometimes dyes are added at the same time, or in a subsequent drumming operation. Here again, the woods of various trees provide important materials for the tanner's use in coloring leather. Other dyes that are used come from coal-tar products and are called "aniline colors." Very clever manipulation of these various dyestuffs is required by the tanner to give his leather the beautiful colors found in modern shoes, particularly shoes for women. While these are made of calf rather than of cowhide side-upper leathers, the dyeing operations are nearly identical in both cases. On cheaper grades of leather, a coating of dry-paint colors or pigments is often applied, instead of aniline or other dyestuffs.

Following coloring, the leather is ready to be stretched and smoothed The side is then laid on a smooth slab and pressed with a blunt knife until it lies flat and until most of the water absorbed in the coloring drums has been squeezed out. Then the moist hides are dried either in chambers flooded with warm air or in ordinary lofts, where the drying is natural. Before the leather is ready for the finishing touches it has to stand for a few days to allow the fat liquor to work more fully into it. Then each side is again moistened with water or dampened sawdust and given a mechanical softening and stretching, after which it is stretched out on boards while still damp and tacked or nailed around the edges, so that the leather lies taut. This pulls out all the wrinkles and takes out most of the stretch. A final drying follows, and the leather, dull and without luster, is ready for finishing or glazing.

Glazing consists of subjecting the leather to friction by rubbing it with a glass cylinder. Where a dull finish is wanted, a revolving brush instead of the glass cylinder is used. For a very high finish, a seasoning is applied, and the glazing is repeated.

Patent leather. No matter how many times the glazing is done, the very high luster of "patent leather" cannot be obtained in this way For this kind of leather, the skins are taken, after coloring, to an operation in which naphtha removes the surface grease left from the fat-liquoring process. Then the skins are spread out, tacked on frames, and coated by hand with special paints and colors. Several coats are usually required, with alternate baking and rubbing down with pumice. In order to make the finish hard, bright, and firm, the leather, following each coat, is exposed to bright sunshine, in winter as well as in summer.

Calf leather. Uppers for the very highest grades of shoes are very frequently made of calf leather, because this is a leather particularly well adapted to withstand scuffs, knocks, and hard wear. Because it

stands up well, is very comfortable, and is of fine appearance, chrome-tanned calfskin is used, not only for uppers for the best of plain shoes, but also for the delicately tinted shoes that today complete the fashionable wardrobe. Calf leather is also employed for making fancy leather for bags, purses, and fittings, for bookbinding, for gloves and garments, and for some kinds of luggage.

Fancy leather. Articles from scissors cases to collar bags, from pocketbooks to shoes and slippers, are made of leather, with almost every color represented. The surface texture varies from hard, smooth finishes to unusual grain designs of many kinds. Leathers for trim, for novelties, for unique application, where appearance is the factor of primary importance, are generally grouped under this classification of "fancy leather." Calfskin is an important fancy-leather material, but there are several others, including the skins of sheep, goat, deer, ostrich, snake, lizard, alligator, shark, and seal. Production varies in quantity, because, except for the first three mentioned, the supply of the birds, animals, reptiles, and fish used in making them is somewhat limited and uncertain.

Horsehide and coltskin. Cordovan leather, so named because it was first made in Cordova, Spain, comes from the butt of horsehide. Cordovan leather, quite like our cuticle or finger nails in texture, perhaps "breathes" less than any other shoe leather in use.

This leather and others made from the same raw material amount in value to 2 or 3 per cent of the total of leather production in this country. Some horsehides are imported from France and from Russia, although, in normal times, the United States is nearly independent of outside sources for this raw material. Colt skins, coming from immature horses, formerly were brought over extensively from Russia. A very fine-grained leather is made from selected horsehide for shoe uppers, work gloves, and rugged garments, and also for a patent leather known as "patent colt."

Sheep and lamb leathers. In addition to fancy leathers, many standard leathers for special purposes are made from sheepskins and lambskins. One important group of such leathers is that produced for making gloves. Lambskins are the most important raw material for this type of leather, which is finished in smooth form, in suede, in mocha, and in napa. The tannage depends primarily on the finish of the leather, and it may be chrome, oil, or of a special nature involving the use of other chemicals. A considerable volume of unsplit sheepskins and lambskins is converted into leather suitable for the linings, stays, and facings of shoes. Depending on the breed of the sheep from which the skins come and the use to which the leather is to be put, tannage is either chrome or vegetable, or in some cases a combination of the two. Leathers for clothing, for buffing wheels, for sweatbands in hats, for parchment—the material used in making such documents as diplomas—for piano parts, and for pouches in meters to measure gas are among the 50-odd special leathers made from sheepskins and lambskins.

A strange member of the sheep family provides the cabretta skins;

they are animals called "haired sheep." They resemble sheep in most respects but differ from them in having hair like that of a goat instead of wool. Slightly more than 3,000,000 cabretta skins are imported each year from Brazil and Africa.

Goatskins and kidskins. Numerically, the goatskins tanned in the United States run high, but the size of the skins is small. Per unit of weight goatskins are the most expensive of the major varieties of hides and skins, being exceeded only by kangaroo skins and a few minor specialties. Europe, east Central Africa, South America, India, and southern United States are the chief producing areas. The goat, like the sheep, is hardy, but its resistance to extreme cold is not so great, and its adaptability to warm climates is proportionately greater.

Early records show that goatskins share with sheepskins the reputation of having been used in making leather in antiquity. As both these skins were a regular source of leathermaking material in those days so, at the present time, they provide us with one of our most important standard shoe leathers, namely, glazed kid. Chrome tannage is employed for making most of our American kid leather. Morocco is a fairly important vegetable-tanned goat leather. Small amounts of goatskin are tanned for upholstery service and for bag and case leathers

Pigskin. The distinctive appearance of pigskin leather gives it a prominence not justified by the amount actually tanned in the United States. A very small number of pigskins are imported from southern Mexico and from the River Plate region, because of their unusual surface texture. The smoothest pigskin comes from Europe, where the animals are treated with as great consideration as are pure-bred cattle in this country. Northeastern United States is the principal domestic source of pigskins for tanning.

Pigskin might be classed as a fancy leather, a luggage leather, or a shoe leather. Removal of the bristles from the skin leaves a distinctive marking that is characteristic. These bristles, deeply imbedded, grow in groups of threes, the holes left on removal of the hair identify this leather. Tanning is made difficult by the high oil content of the pigskin, and the supply of the raw material suited to tanning is governed somewhat by the packing processes that precede the take-off of the skins.

Deerskin. Tanned with oil or with a chemical called "formaldehyde," and more recently with chrome, deerskin makes the buckskin leather of commerce. This is important as a glove material, for use in garments such as riding breeches, to some extent for novelties, for piano actions, and for shoe uppers. The glove and garment industries use considerable quantities of buckskin leather made from the skins of animals of the deer species. These skins are almost entirely imported either from Latin America or from Canada, although the number of countries contributing to our supply is great, including northeastern Africa, southern and eastern Asia, and the East Indies.

Ostrich skin. The tiny rosette that marks ostrich skin makes this leather distinctive. It is peculiar also in that it is the only type coming from the skin of birds—birds that are raised principally on farms in

South Africa. Since plumes are the product for which these birds are raised, the skins are taken from animals that die or that have passed their period of usefulness, so the amount of the leather tanned is very small. Ordinarily, this leather is finished in the natural color, which is very pleasing. Because of the relatively small size of the skins, only comparatively small articles can be made of this rosette-marked leather. The grain of genuine ostrich is quite frequently embossed on calf and cowhide, because these skins are much more readily available than is ostrich.

Snakeskins and lizard skins. Snakeskins vary a great deal in appearance, and since the tanning process serves to stress the original markings, leathers made from these skins are peculiarly distinctive. Lizard skins fall in the same class. The pythons, boas, and anacondas, because of their size, are of the greatest value for leathermaking. Other groups include the water snakes and the poison snakes, which produce the most beautiful effects and colors, and are therefore widely sought in the desolate jungles and waste places throughout the world. Because the available supply of these skins cannot meet the demand for them, they are simulated by embossing other leathers of greater strength—including sheep, goat, and calf—with a snake grain.

Alligator skin. The manufacture of alligator leather started at a time when there was an abundance of these animals in Florida, and alligator leather continues to be almost exclusively an American product, although it has now become necessary to import a considerable number of the skins. Differing from most other leather-producing animals, the alligator requires more than 100 years to come to its full size, and for that reason, dependence for raw material is necessarily upon those regions where alligators thrive in the wild state. Latin America and Africa are now shipping these skins to American tanneries.

Skins of marine origin. The hair seal, walrus, and shark are the principal marine sources of materials for the tanner. The first two of these are brought in by ships that set out once a year from Newfoundland and from Norway to the subarctic region, where the seal and walrus flourish. Shark skins come from tropical waters, particularly off the coast of Australia.

Seal leather. Heavier sealskins make a grade of vegetable-tanned leather that is used for covering traveling bags and cases, but the bulk of sealskin is used for the production of regular fancy leather. It is fairly strong, but the supply is not sufficient to allow its use in such articles as shoes, although a limited amount is used in the British Isles for furniture upholstery.

Walrus and buffalo leather. Walrus leather is chiefly important because it is both very thick and very tough, having a coarse texture that fits it well for the buffing wheels used by jewelers and silversmiths in polishing their wares. No other leather has been found that takes the place of walrus for this service.

The only other important raw material from which leather is made is the hide of the true buffalo, an animal common to southern Europe, east

of Italy, and to southern Asia. The buffalo bears a resemblance to our Shorthorn cattle in appearance and is a beast of burden, particularly in semitropical rice fields. Its hide is coarser than that of cattle, and, in normal times, it is used only to a very limited extent in this country for leathermaking. Buffalo leather, having a grain quite similar in appearance to that of walrus, is largely confined, in normal times, to making luggage; but when a great shortage of cattle hide exists, it can be made into a somewhat porous leather for shoemaking.

Kangaroo skins. The skins of kangaroo and wallaby, a species of kangaroo, make one of the most perfect upper leathers. Until about 50 years ago, these skins were thought valueless, until an American tanner discovered their usefulness. Since then, the production of kangaroo leather has been a comparatively small but stable branch of the industry. American tanners import approximately 1,000,000 kangaroo and wallaby skins a year, chiefly from Australia. Kangaroo leather differs from other types in having a particularly tightly woven skin structure, the closely intertwined fibers running in all directions. Because of this peculiar structure, the leather is the strongest known for a given weight and thickness. In service it does not readily scuff or crack, and it makes shoes both attractive in appearance and extremely serviceable. Many athletic shoes, where both strength and comfort are extremely desirable, are made of kangaroo leather.

Supremacy of American leather. The ramifications of the leather industry are many, and it may be safely said that there is no industry wherein greater care is exercised to turn out an honest and dependable piece of merchandise. No two hides are alike, just as no two people are alike, and it practically becomes a case of taking infinite pains with each individual hide. A hide is nature's product; it rarely goes wrong if properly treated, and a well-tanned piece of leather is something that cannot be approached by anything that man can fabricate. It has that inherent quality of containing millions of fibers, closely knit, which, in tanning, become stronger than in nature and still retain their pliability and their imperviousness to water and also still allow the leather to breathe by admitting a certain amount of air, just as they did when they were on the creature's back. The other constituent parts of the hide are made nearly indestructible by tanning, and the leather becomes a product which it is impossible to duplicate and which has proven its worth over centuries of time and has never been approached for quality in any way.

Today, tanning follows approved scientific methods. In the old days, the quality of the leather made was due entirely to the skill of the tanner; tanning was an art and not a science. While it is not strictly true to claim that conditions are now reversed, it is fair to say that leather is made today with far greater certainty, by much more definite and scientific methods, and under laboratory control. A laboratory is essential in every modern tannery. To insure proper quality, strength, and so forth, raw materials are most carefully tested before being used. The manufacturing processes are controlled with the help of information

supplied by the laboratory. Finished goods are expected to conform to standard specifications. The scientist has a very difficult problem on his hands in his effort to reduce the making of leather to a mathematical certainty, but he is steadily making progress. The tanners, appreciative of the value of fundamental knowledge of the laws governing the making of leather, all the way from the preparation of the raw material to the finish of the final leather, have established a research laboratory at the University of Cincinnati, where the entire time of a most able staff is devoted to exhaustive study of this subject from all sides—chemical, physical, and bacteriological. The leathers made in the United States are unexcelled in quality by the product of any other country, and the forward strides constantly being made by the leather industry promise continued supremacy for American tanners.

Marketing Hides

Methods of marketing hides. The marketing of hides is so interwoven with their quality and condition that it is difficult to give a clear picture of how they are marketed.

The primary distinction in cattle hides produced in this country is between packer hides and skins, and between country hides and skins. Packer hides are again divided between big packer hides and small packer hides.

Packer hides and skins are taken off in establishments where the slaughter is of a wholesale character and where labor is employed for the one purpose of removing the hide. In those large establishments, the work involved in skinning the animal is so divided that each operator performs only part of the task and, therefore, becomes very proficient in what he does. The hides are taken off in large numbers and are uniformly skinned, graded, and cured. The result is a product of uniform selection, good pattern, and good trim, with a minimum of butcher imperfections.

Country hides and skins are taken off by farmers, ranchmen, or local butchers, or by other helpers who are usually inexperienced in skinning; the hides, therefore, show a number of cuts, which obviously lower the grade of the leather that is produced therefrom. Country hides include hides removed from animals that have died from disease or accident, as well as from animals that are slaughtered in small shops for food. These hides originate in small numbers and are scattered all over the country. They are seldom treated with care and are, therefore, of an inferior quality, which is usually reflected in the price.

The packer hides are usually sold direct by the packing company to the tanner. The transaction for the smaller tanner is usually handled by a broker. Country hides are usually handled through dealers and are purchased for the tanners either direct from the dealers or through the tanner's brokers

Foreign hides are usually purchased through brokers, either in this country or abroad. Inasmuch as the hides from various countries are

handled in various ways, it is difficult, if not impossible, to give the marketing conditions in each instance.

Methods of Financing

The capital invested and methods of financing in the tanning industry vary from one company to another. There are many tanners in the United States who operate but one plant. This very frequently is a small operation, which is personally financed by the owner, together with such assistance from local banks as may be required from time to time to take care of peak loads. The large tanning companies are usually stock companies and are, therefore, financed through the issuance of preferred and common stocks and, in some cases, bonds. In these companies, it very frequently becomes necessary to make loans at the banks This is usually the case when it is necessary to carry increased inventories.

Important Legislation

Important legislation affecting the tanning and leather industries in recent years has been the placing of a tariff on the importation of hides and skins of the bovine species and the compensatory duty placed on leather at the same time. There was only one other time in the history of this country when we had a tariff on the importation of hides. Such a tariff does not appear to be economical for the reason that the production of hides and skins in the United States is not sufficient to meet domestic requirements. The tariff, therefore, places a hardship upon the American public to the extent of the tariff imposed.

There is, of course, other legislation affecting the industry, some of which is local, relating to compensation insurance and labor, as well as local and Federal laws relating to taxation and sewage disposal.

Possible Future Developments

As in many other industries the possible future developments of the leather industry are dependent largely upon research. In order to provide for development along this line, the National Organization of the Tanning Industry has established a research laboratory in connection with the University of Cincinnati, where work is going on constantly, confined entirely to research; and it is highly probable that, through this laboratory, the industry may develop, in the future, many new operations or methods of tanning.

The economic significance of the leather industry to our present development. Inasmuch as the leather industry is one of the fundamental industries of the world, it is obvious that it plays a very important part in our present and future economic and industrial development As leather is used for so many purposes and in so many ways by so many of our large industries, it naturally has a very important bearing

upon industrial development. The value of this influence cannot be estimated in a monetary way, but as there is no substitute to take the place of leather, we can safely say that we are dependent upon the production of leather for the progress and continuance of industry as a whole.

14

The Sugar Industry

Our national sugar bowl must be filled to the tune of more than 5,500,000 tons annually, and two thirds of this requirement is the product of the great seaboard cane sugar refineries. The sugar refining companies represent a capitalization exceeding $200,000,000 and furnish employment directly to some 18,000 wage earners. Their input is raw cane sugar which comes chiefly from Cuba, Hawaii, Puerto Rico, and the Philippines, with a minor proportion from Louisiana and a very small quantity from elsewhere in the world. The remaining third of the sugar consumed in the United States consists of home-grown beet sugar, and direct-consumption cane sugars manufactured in Cuba, Puerto Rico, the Philippines, and Hawaii, along with a small quantity of "plantation whites" made directly from the cane in Louisiana. The following table shows the sugar consumption of the United States, classified as to source:

TABLE I

CONSUMPTION OF SUGAR IN THE UNITED STATES[1]

	1939		*Average for 1937–38–39*	
	Tons 2,240 Pounds	*Per Cent*	*Tons 2,240 Pounds*	*Per Cent*
United States refined cane sugar	3,303,425	58.5%	3,545,586	62.8%
United States beet sugar . . .	1,391,972	24.6	1,201,966	21.3
Cuba, United States Insular, Louisiana, and foreign white cane sugars	953,116	16.9	900,163	15.9
Total	5,648,513	100.0	5,647,715	100.0

History of Cane Sugar

Early history of sugar. Crystallized sugar was undoubtedly first obtained from the sugar cane (*saccharum officinarum*). The origin of

[1]Based on estimates from Willett and Gray's *Weekly Statistical Sugar Trade Journal* (January 18, 1910), page 19.

the sugar cane is lost in the forgotten legends of mythology, but some mention is made of it in written records that go back far into antiquity. Early Chinese writings indicate that it was first known in India. The prophet Jeremiah refers to "sweet cane from a far country." In the records of the expedition of Alexander the Great down the Indus in 325 B.C., Nearchus, an admiral of the expedition, mentions "honey-bearing reeds," undoubtedly a reference to sugar cane.

As to the production of crystallized sugar from the cane, this may have been accomplished, though probably in a very crude way, at least as early as the time of Nero. Dioscorides, who lived during the reign of Nero, wrote: "There is a sort of hard honey which is called saccharum (sugar) found upon canes in India. It is grainy like salt and brittle between the teeth, but of sweet taste withal." At any rate the art of sugar manufacture was known in the seventh century, for Tai-tsung, Emperor of China from 627 to 650 A.D., sent ambassadors to India to learn how to extract syrup from the sugar cane and to boil down the liquid into a soft paste similar to the darkest grades of modern brown sugar, but certainly of inferior quality.

The Arabs brought sugar cane from the Nile Valley to Sicily, whence it spread to Spain and successively to other countries bordering on the Mediterranean. In the fifteenth century, the King of Portugal sent as a personal gift to the Governor of the Canary Islands cuttings of the cane. Cultivation was successful and from these islands sugar cane spread to Brazil, San Domingo, and later to Mexico. From Mexico the Jesuit missionary fathers of San Domingo carried it to Louisiana in 1751, but more than 40 years elapsed before sugar was successfully produced from the cane.

Cane sugar in Louisiana. As early as 1759 a mill was built, but efforts to crystallize sugar were unsuccessful at that time. Don Antonio Mendez, a Spanish colonist and government official, with the help of a Cuban sugar maker, succeeded in graining sugar, of which a few barrels were produced in 1791. Three years later Etienne de Boré planted seed cane which he had purchased from Mendez, and in the same year, 1794, he produced a crop of sugar which sold for $12,000. Many other planters quickly followed the example of de Boré in the manufacture of sugar from the cane and most of them grew wealthy through this enterprise

Ever since those early days Louisiana has continued to produce sugar but it has not shown the progress in sugar production enjoyed by Cuba and our insular possessions, which have more favorable climatic conditions and lower production costs. In addition Louisiana suffered the ravages of a cane pest, known as mosaic disease. Sugar production in Louisiana declined from a maximum of 355,000 tons in 1904-1905 to 42,000 tons in 1926-1927. Since 1926 a more resistant variety of cane, newly developed in Java, has been introduced into Louisiana, and there has been a partial recovery in the industry. The 1939-1940 crop amounted to 401,000 tons.

Early refining. The refining of sugar, in but a crude way, was introduced by the Egyptians in the eighth century. The development of

refining methods must have been exceedingly slow during the succeeding centuries, for it was not until 700 years later that the advent of sugar loaves was recorded. In the fifteenth century a resident of Venice received a reward of 100,000 crowns (about $112,000) for the invention of a method of molding sugar into loaves called *"pains de Venise."* More centuries elapsed before pure sugar was produced at a price at which it could be enjoyed by all; indeed, as late as 1742 the market price of sugar in London was $2.75 per pound. From that time the consumption of sugar has grown until today it constitutes one of the largest single items of food to pass through the hands of wholesale and retail dealers.

Beginning of refining in the United States. The cane sugar refining industry of the United States is said to date from the establishment by one Nicholas Bayard of a sugar house in New York in the year 1730. Previous to that time the purification of sugar had been practiced in a crude way and on a small scale by bakers who resided in the seaboard towns, where casks of Muscavodo and Cassonade sugars from the West Indies were frequently landed. The former was a low-grade raw sugar, imperfectly drained of its molasses, whereas Cassonade was freed from molasses by being poured into conical molds and covered with damp clay.

Early refining methods. Bayard and later pioneers in the industry heated the raw sugar with lime water and added raw eggs to coagulate impurities, which were then removed by skimming and filtering. The partially purified liquid was concentrated in open kettles until crystallized and then poured into conical molds. At the bottom of each mold was a small opening for drainage of the mother liquor. The mass in the mold was covered with moistened clay, the water from which, draining down through the sugar, removed the adhering molasses. The loaves were finally removed and dried in ovens. The single-refined loaves, before drying, were frequently melted, and the whole process was repeated. In this way "double-refined" loaf sugar was produced. Thus it will be seen that in those times, as today, the process of sugar refining was essentially one of purification by recrystallization.

Boneblack and the vacuum pan. Immediately after the Revolution, animal blood, which had been in use for a considerable period in Europe, replaced eggs as a clarification agent. Beginning about 1830 methods that were forerunners of modern practice began to be adopted. The vacuum pan and animal charcoal were introduced in American refineries, while the old blood defecation gradually gave way to defecation by chemicals, such as a combination of alum and lime; then phosphoric acid and lime with bag filtration took the place of skimming. During all this time and, in fact, until some year after the Civil War, refiners practiced the ancient method of purging the sugar of its syrup, which involved thousands of molds, vast floor areas for storing these molds, and great waste of labor for handling and of time for purging and drying the sugar.

Modern centrifugal machines finally replaced the old "fill house" of

the seventies and eighties, and the drying ovens were superseded by the modern "granulator."

Pioneers in refining. From the venture of Nicholas Bayard in 1730 until the cost of refining sugar was lowered by centrifugal separation to a point that paved the way for a remarkable expansion of the industry, the path of progress was blazed by worthy pioneers whose enterprise and thrift laid the foundations of that great branch of the nation's business, our modern sugar refining industry. Archibald, of the firm of Archibald and Delafield in New York, was an early genius in the inventive field, as is shown by the granting to him of many patents for improvements in manufacturing methods and equipment. His firm seems to have been first in this country to adopt boneblack filtration and the vacuum pan. Professor Chandler, of Columbia University, was the outstanding pioneer in the chemistry of sugar refining, a department of the industry that has played no small part in developing the refining process to its present high state of efficiency. The polariscope, an optical instrument used to determine the percentage of sugar in all classes of saccharine products, was first used in America by one of the refineries in Philadelphia. Among the later technologists of the industry no name is so well known and so universally revered as that of Henry E. Niese. During his association of more than 50 years with the industry, and until his death in 1929, this dean of American sugar refiners was at some time the consultant of nearly every sugar technologist in this country and of many abroad.

Family ownership. The ownership and business management of the American refining industry was somewhat of a family affair from the time of its inception until almost the end of the last century. Often started by partners, a refinery would pass to the sons of one or both and, in turn, to their sons, through several generations. Many of these families reaped large fortunes from the profits of their refineries. When, in the last quarter of the century, competition became ever keener, financial strength, the introduction of modern machinery, and perfection of the process determined the survival of the fittest. The Havemeyer family of New York and Brooklyn had been connected with the refining industry since 1805, and the decade of the eighties found their descendants occupying a leading position in its commercial and operating fields.

H. O. Havemeyer and consolidation. Henry O. Havemeyer saw the need for both physical and financial concentration and consolidation of refineries, and in 1887 he organized the Sugar Refineries Company. Out of this corporation grew the American Sugar Refinery Company (1891), which produces about one quarter of the cane sugar refined in the United States.

Mr. Havemeyer continued to lead the great enterprise he organized until his death in 1907, and earned himself a place among the great generals of American industry.

The volume basis. During the years that followed this first great consolidation many small and uneconomical refineries were dismantled. The best of the existing plants were enlarged and improved, and the

new refineries that have since been erected are titans compared to the old-time sugar houses. Only by great volume can the unit cost of production be maintained at a competitive level in this industry.

History of Beet Sugar

While sugar refining was marching along in the front rank of American industrial development, the beet sugar industry was established, wavered uncertainly for a time, but finally, nurtured by bounties and highly protective tariffs, found a foothold in the West. It now furnishes more than one fifth of the total quantity of sugar consumed in the United States.

Early history. Andreas Marggraf of Berlin, Germany, first demonstrated in 1747 that sugar could be extracted from beets and crystallized. Forty years later a pupil of Marggraf named Franz Karl Achard succeeded in increasing the sugar content of beet roots by cultivation and made sugar therefrom in something like a practical way. The work of Achard attracted the attention of Friedrich Wilhelm III, King of Prussia, who provided Achard with money for a beet sugar factory that started operations in 1802. Other factories followed in Prussia and efforts were also made in France to manufacture sugar from the beets. By 1811 it had become evident that beet sugar manufacture could be made a successful undertaking

On March 25 of that historic year, Napoleon Bonaparte, in order to relieve the distress of the French people, whose supply of imported sugar was cut off by the British blockade, issued the famous edict that established the beet sugar industry in France. From that moment its development was rapid

The advantage of having a domestic source of sugar supply that would not be cut off with each new war, was patent to the nations of Europe, and the new industry was accordingly encouraged by bounties and protective tariffs. Competitively it was helped by the abolition of slavery in one after another of the principal cane-growing lands of the world (1834 to 1880). The world production of beet sugar steadily climbed at a more rapid rate than that of cane sugar, until in 1896-1897 it substantially equaled the latter. This relative position was maintained with little change for about 17 years—that is, until the outbreak of the War of 1914 to 1918.

Devastation by the First World War. As a result of the First World War, in which vast areas of beet fields had been turned into battlefields and industry had been generally demoralized, Europe's sugar crop fell off from about 8,000,000 tons to a low of 2,600,000 tons in 1920. The demand of Europe for outside sugars that accompanied the diminution of European production was the signal for enormous expansion in the cane sugar field, notably in Cuba. The table on page 300 gives world production of cane and beet sugars for a few early years at the start and close of the War of 1914 to 1918 and thereafter at 5-year intervals. These figures illustrate the sweeping effect this war had upon the world's sugar

crops and the subsequent recovery of beet sugar, nurtured by legislation in many countries.

Beginnings of beet sugar in the United States. The beet sugar enterprise first to achieve success in the United States was started by E. H. Dyer at Alvarado, California, in 1879. Dating from 1830, in which year James Vaugh and James Ronaldson built a small factory at Philadelphia, sporadic attempts had been made to start the manufacture of beet sugar in no less than 10 states, including Massachusetts, Wisconsin, Utah, and California. The same E. H. Dyer had previously essayed a short-lived venture at Alvarado 10 years prior to the successful enterprise above mentioned. All these attempts failed, however, because of insufficient knowledge of methods for the culture of sugar beets and the manufacture of sugar therefrom. Following Dyer's successful venture, Claus Spreckels, who was destined to become an outstanding figure in the sugar industry of America, built a beet sugar factory at Watsonville, California in 1888; and in the following year the Oxnard Brothers, who had been engaged in sugar refining at Brooklyn, New York, started a factory at Grand Island, Nebraska. This enterprise eventually grew into the American Beet Sugar Company, now known as the American Crystal Sugar Company. A number of other beet sugar projects were started only to end in failure.

TABLE II

WORLD SUGAR PRODUCTION[2]
(In Tons of 2,240 Pounds)

Year	Production Cane Sugar	Production Beet Sugar	Production Total Sugar	Percentage of Cane Sugar
1885–1886[a]	4,289,300	2,229,973	6,519,273	65.8%
1895–1897[a]	5,091,857	4,954,032	10,045,889	50.7
1903–1904	6,838,931	6,820,204	13,659,135	50.1
1913–1914[a]	9,801,536	8,634,942	18,436,478	53.2
1917–1918	12,365,569	5,015,262	17,380,831	71.1
1919–1920	12,227,125	3,273,798	15,500,923	78.9
1924–1925[f]	15,895,336	8,093,453	23,988,789	66.2
1929–1930	17,633,924	9,175,319	26,809,243	65.8
1934–1935	15,526,269	9,530,585	25,056,854	62.0
1939–1940	19,330,205	11,115,917	30,446,122	59.5
1940–1941	19,037,427	10,859,873	29,897,305	57.0

[a] Including an estimated production for India not given in Willett and Gray.

Legislative encouragements and discouragements. The earlier beet sugar undertakings were generally motivated by some form of bounty or tax exemption granted by the states. In several cases, however, state bounties were quickly repealed or were declared unconstitutional by the courts, all of which brought rather more downs than ups to the infant industry.

[2] *Ibid.*

The McKinley Tariff Act of 1891, although admitting foreign sugar without tariff duty, provided for a bounty of 2 cents per pound on sugar produced in the United States testing over 90 degrees (by polariscope), and of 1¾ cents on sugar testing 80 degrees to 90 degrees. Beet seed and sugar machinery were admitted free of duty. The constitutionality of the bounties was questioned and the matter was still before the Federal courts, when the Wilson Bill of 1894 was enacted, repealing the bounty provision and fixing the duty on sugar at 40 per cent ad valorem. As raw sugar was then worth about 2.5 cents per pound, protection was afforded to domestic sugar to the extent of only 1 cent as against 2 cents per pound under the bounty system.

Revival due to high tariff of 1897. A fresh impetus was given to beet sugar production by the Republican tariff of 1897, which fixed a basic duty of .95 cents per pound on sugar testing not above 75 sugar degrees, and of .035 cents per pound additional for each additional sugar degree (one sugar degree equals 1 per cent sucrose by weight). This legislation acted as a powerful stimulus to the beet sugar industry, and more than 20 new factories were built in the ensuing 2 years. Only about half of these were successful, but the industry had now gained a firm foothold and there was no longer any question but that beet sugar had come to stay, with the help, to be sure, of adequate tariff protection.

TABLE III

UNITED STATES BEET SUGAR PRODUCTION FROM 1930 TO 1940

Year	*Sugar Production in Tons of 2,240 Pounds*	*Number of Factories Operated*
1930–1931	1,075,688	78
1931–1932	1,025,217	66
1932–1933	1,206,656	75
1933–1934	1,466,053	84
1934–1935	1,035,014	75
1935–1936	1,052,207	77
1936–1937	1,167,530	82
1937–1938	1,147,185	87
1938–1939	1,485,021	87
1939–1940	1,462,605	81

Beet sugar threatened by low tariff of 1913. Once more the specter of free sugar loomed under the Democratic tariff law of 1913, which provided that all sugar should be admitted free of duty after May 1, 1916. The free clause was repealed, however, just before it was to have become effective, and beet sugar prospered under war prices. Subsequent tariff acts have successively boosted the protection to domestic sugar and recently the quota system under reduced duties has protected it; otherwise, that industry would have passed out of existence in recent years because of the low sugar prices brought about by excessive world production of cane sugar.

Firmly established (1900 to 1906). The years 1900 to 1906 formed a period of intense activity in the beet sugar industry. During those years

the Great Western Sugar Company and the Utah-Idaho Sugar Company, among others, built several new factories and laid the foundations of a widely spread and important industry. In 1906-1907 there were 63 factories in operation, and under the war stimulus the number of factories operated in any one season increased to a maximum of 97 in 1920-1921, the production that year being 969,000 tons of sugar.

About 1,463,000 tons were produced by 84 factories in 1939-1940. Table III shows the production of beet sugar in the United States in the last 10 years.[3] The output from 1934-1935 on was influenced to some extent by quota regulations.

Our Cane Sugar Industry Today

At the present writing there are 18 great refineries on or near the seaboard of the United States using the boneblack process. These are owned and operated by 13 different companies. Their daily melting capacity is estimated to be 51,250,000 pounds of raw sugar—an average of 2,850,000 pounds for each. The largest unit now operating is rated at 5,500,000 pounds and only 3 are under 2,000,000 pounds in capacity. In addition, there have sprung up in recent years several refineries that use vegetable carbons or chemical methods of refining in place of the standard boneblack process. The combined capacity of these plants is about 350,000 tons.

War expansion. Influenced by foreign demand during and after the War of 1914 to 1918, several refining companies greatly increased their capacity, but with the recovery of beet sugar production in Europe the export demand naturally dwindled. Furthermore, the domestic beet sugar crop climbed from a prewar high in 1914 of some 650,000 tons to nearly 1,500,000 tons in 1933, and white sugars manufactured in Cuba and Puerto Rico began to compete in the markets of the American refiners. White sugars other than American refined (including beet sugar) comprised in the year 1933 the important quantity of 776,000 tons, or nearly 15 per cent of our total sugar consumption. Beginning with 1934, quota restrictions have somewhat checked the influx of offshore white sugars; nevertheless, under these conditions the additional refining capacity provided under war stress has remained largely unutilized. The situation naturally has led to the keenest kind of competition for business.

Location of refineries. Geographically, the refineries are distributed as follows:[4]

Atlantic group	11
Gulf group	5
Pacific group	2
Total	18

Water-front location on a good harbor is in general essential to a modern refining enterprise. The raw sugar arrives in ships, and the un-

[3] *Ibid.*

[4] See Table VIII, page 325, for the location and annual melting capacity of 18 refineries

loading thereof directly to the refinery dumps and storage sheds is far more economical than to rehandle and transport it to an inland location. Adequate rail facilities for shipping the refined product are also important.

The raw product. The raw product comes principally from Cuba, Puerto Rico, Hawaii, and the Philippine Islands, augmented at the Gulf refineries by the relatively small raw sugar production of Louisiana. The raw product is a crude crystallized sugar, grayish brown in color, containing about 96 per cent to 98 per cent sucrose. It is manufactured from the juice of the sugar cane. After a crude clarification process, involving a coagulation and settling out of insolubles by the application of lime and heat, the juice is boiled under vacuum until crystallization takes place, and the crystals, separated in centrifugal machines, constitute the raw material transported to this country for refining. The importance of sugar to the shipping interests will be appreciated when it is borne in mind that over 4,500,000 tons of raw sugar are brought to the refineries annually, besides the 500,000 tons of white sugar that are imported for direct sales. Raw sugar arrives at the refinery packed in bags ranging in weight from 100 pounds in the case of Hawaiian and some Philippine sugar to the 325 pound bags of Cuba. The bags are made up into slings weighing a ton and hoisted from the vessel's hold by the ship's tackle. The sling is then transferred to a hoist supplied by the refinery and transferred from the deck either to an electric truck or to a belt conveyor on the dock.

Weighing and testing. Puerto Rican, Hawaiian, and Philippine sugars (up to 850,000 long tons per annum) are not subject to tariff duty. Cuban and all other foreign sugars are weighed, sampled, and tested by representatives of the United States Treasury Department for the purpose of determining the amount of duty to be paid thereon. Each bag is stabbed with a long pointed instrument called a "trier." This has a groove in which a small portion of the bag's contents lies when the trier is withdrawn. When the sample cans are filled, they are sealed, conveyed to a Government laboratory, mixed, and tested in a polariscope to determine the sucrose content. Another weight and another sample are taken by representatives of the buyer and seller, for the purpose of determining the settlement weight and test on which the sugar is paid for. Each sample represents usually about 2,000 bags. After thorough mixing, small portions are sent to the buyer's chemist and to the seller's chemist, and to a laboratory maintained jointly by the buyers and sellers, known as the New York Sugar Trade Laboratory. The two of the three tests which are closest together are retained, and the mean of these tests is the settlement polarization. The third test is thrown out, so that if either buyer's or seller's chemist should deliberately falsify tests, it would be of no avail.

Refining process. From the dock the bags are carried by crane or truck to a dump, where they are opened and the sugar is emptied into a crusher. A bucket elevator carries it thence to the top of the refinery "wash house," where the refining process begins. The first step in the refining process, called "affination," is a washing process which separates the

mother liquor surrounding the crystals of raw sugar. The sugar is first mingled in a long scroll conveyor with washings from previously affined sugar. The resulting pasty mass called "magma" or "fillmass" is whirled in a centrifugal machine with a perforated basket, the contents of the basket being sprayed with water. The liquid portion is thrown off and collected, while the sugar crystals remain against the perforated lining of the basket. At this point the sugar has a purity of 99 degrees.

After the washed sugar is dropped from the centrifugal basket, it is melted in hot "sweetwater," which simply means a dilute sugar solution that results from some washing or sugar-dust collecting process in the refinery. The density of the solution is adjusted to about 60 per cent solids. The melted washed sugar is pumped to tanks called "blow-ups," in which agitation is effected by blowing in compressed air at the bottom. It is then heated to 180 degrees F. The reaction of the solution, which is slightly acid by nature, is adjusted to the neutral point by the addition of milk of lime. Diatomaceous earth is then added as a filter aid, and the liquor is run through leaf pressure filters such as the Sweetland or Vallez types. The effluent, while brilliantly clear, has a strong yellow color, as little other than the suspended impurities have been removed at this point.

The major purification is effected by percolation through granular animal charcoal, manufactured from bones, and commonly called boneblack or bone-char. Boneblack has the peculiar power of "adsorption" that is common to many porous substances. It removes from the sugar liquors and retains in itself to a marked degree both mineral salts and organic substances such as coloring matters. This process of purification, sometimes called epuration, is carried on in large cylindrical cisterns known as char filters, each of which is approximately 10 feet in diameter and 20 feet deep, and almost completely filled with boneblack. The liquor is run on at the top, passes through the entire column of bone-char, and emerges colorless. It continues to run practically colorless for several hours, eventually passing to a straw shade or light yellow as the char gradually nears exhaustion. When a filter is completely exhausted, the liquor is displaced by water from the top downward, the effluent of constantly decreasing density being evaporated down until a point is reached where recovery by evaporation will no longer pay. The filter is then washed to the sewer for 10 to 12 hours, whereby nearly all of the "adsorbed" impurities are again given up.

The char is finally dried and heated to redness in closed retorts to destroy the last traces of organic impurities and to restore its adsorptive quality. Boneblack can be re-used many times in this way; its total life is from 3 to 5 years.

The char-filtered liquor is concentrated in a multiple-effect evaporator in vacuum to about 68 per cent solids. It is then transferred to a vacuum pan and boiling is continued until crystals have formed and have grown to the size desired. Sugar liquor boiled at atmospheric pressure, or anywhere near it, would caramelize rapidly with serious discoloration and heavy loss of sugar, so all boiling operations are conducted under a vacuum, with correspondingly reduced temperature.

The syrup, or mother liquor, is separated from the sugar crystals in centrifugal machines, and the retained sugar is washed with pure water, which leaves it snow-white and practically 100 per cent pure. The centrifugal syrups are mixed with the later, darker-colored runnings of liquor from the char filters and are reboiled, producing 2 or 3 additional crops of sugar which can be washed up to whiteness, and also second sugars, which are remelted and char-filtered following the washed raw sugar. The raw sugar washings referred to in our description of the affination process are press-filtered and then char-filtered two or more times, finally merging with the lower refined centrifugal syrups prior to crystallization. Soft or brown sugars are produced from the syrup from the last crop of granulated sugar.

The white granulated sugar from the centrifugal machines is dried in large revolving cylinders called granulators through which heated air is passed. It remains now only to eliminate oversized crystals and lumps by passing the sugar through vibrating screens, after which it is run into storage bins and therefrom packed in barrels, bags, or cartons, as desired. Soft sugars are not dried but are packed as they come from the centrifugal machines, containing 3 per cent to 4 per cent moisture. Crystal Domino Tablets are made by the Adant process, named for its inventor. In this process the purest and whitest sugar that it is possible to manufacture is formed into large slabs, which are sawed into strips, then clipped to the size of the individual tablets. By this means the glistening crystal surfaces are preserved. Cube sugar and pressed tablets are made from pure white sugar crystallized in the usual manner and afterward molded into the desired shapes by the aid of machinery, a very interesting process from a mechanical standpoint. Mechanically interesting also are the machines that fill cartons with a definite net weight of sugar, seal them, pack them into fiber containers, and seal the containers. The different grades of powdered sugar are made by grinding granulated sugar and separating the different products in silk bolters.

It will be seen that the refining of sugar is essentially a process of recrystallization, but the purification effected while the material is in solution is extremely important. The coloring matter present in raw cane sugar is of such nature that some of it becomes occluded in the crystals, making it impossible to form colorless crystals, however well washed, from an undecolorized liquor. With beet sugar this is not the case. White beet sugar can be boiled from a highly colored liquor; hence the beet sugar factory does not need the elaborate plant for bone-black filtration that is so essential to a cane sugar refinery.

Refined products. One hundred pounds of raw sugar of the standard 96-degree test are converted by the refining process into approximately 93½ pounds of white refined sugar and 4 pounds of final syrup or molasses. The remaining 2½ pounds represent the impurities removed by the process and a fractional percentage of sugar lost in refining When soft or brown sugars are produced, the quantity of final syrup that results is diminished, as soft sugars retain a proportion of the syrup from which they are crystallized. White sugar is crystallized or screened into many

different grain sizes for various uses, from the very fine fruit and berry sugars to crystals of one quarter inch or more in length. The most generally used grade and that which constitutes the great volume of a refinery's production is "fine" or "extra fine granulated." This is the usual household granulated sugar, and is also widely used by manufacturing confectioners, bakers, canners, and, in fact, in most industries where a sweetening agent is required. Many manufacturers prefer a coarser grained sugar for special purposes, however, and hence the grades known as "medium granulated," "standard granulated," and others.

One of the pulverized grades, a coarse powdered sugar of uniform particle size, is the ideal table sugar for fruits, cereals, and iced beverages. Other powdered grades in the order of fineness are "coarse," "standard," and "confectioners'," or "XXXX powdered," sugar. The last named is an impalpable powder and is the proper sugar for cold icings. It is also employed extensively by manufacturers, notably in the chocolate industry. Tablets and cubes are made in a variety of shapes and sizes for sweetening tea, coffee, and other hot beverages. Soft or brown sugars, marketed by most refiners in 10 or 12 grades according to color, are suitable for use in glacé icings, dark-colored bakery products, baked beans, and mincemeat.

The final syrup of a refinery from which no more sugar can be extracted may be turned out either as blackstrap molasses, which finds use in the manufacture of cattle feeds and in the distilling industry, or as filtered refiners' syrup. The latter is sold for mixing with commercial glucose or with sugar syrups to make table syrup.

Inspection. Every modern refinery maintains an elaborate system of inspection and laboratory control in order to insure the quality of its products, to obtain the maximum extraction of sugar with minimum syrup or molasses production, and to minimize chemical destruction and mechanical loss of sugar in the refining process. Also, every possible precaution is taken to prevent contamination of the finished product with foreign material of any kind. By means of automatic machinery the sugar is packed in sealed cartons or bags and sent into the household without being touched by human hand.

Marketing. Refined sugar is sold by refiners for domestic use at a basis price for fine granulated in 100-pound bags, plus or minus a differential for most other grades and styles of packing. A discount of 2 per cent for cash in 7 to 10 days is customary. In general the smaller packages and barrels are higher in price than bulk bags, while tablets and other fancy grades command still higher differentials because of their greater cost of manufacture. Soft sugars, since they contain less sucrose than granulated, when packed in bulk carry minus differentials. The price decreases from grade to grade as the color darkens. Thus, a "Number 5 soft," light yellow and testing, say, 90 degrees is quoted at 25 cents per 100 pounds under basis price, whereas a "Number 13 soft," dark brown and testing 82 degrees, carries a differential of 65 cents per 100 pounds, the decrement being 5 cents per grade.

Selling for export. Sugar for export is generally sold for the domestic

price less the recoverable tariff drawback, which at present amounts to about $1.95 per 100 pounds maximum. Formerly, in order to recover drawback, the refined sugar exported had to be identified as having been actually produced from duty-paid raw material. The tariff law of 1930, however, permits the payment of drawback on exportations of refined sugar, whether or not produced from duty-paid raw sugar, provided that the refiner designates an equivalent amount of duty-paid raw sugar of like kind and quality, imported by him not later than the date of production of the refined sugar exported and melted within a year of its date of receipt. This provision of the law is known as the privilege of substitution.

Competition. Competition in the industry is free and open. The efforts of the refiners to keep their big plants running on a paying volume basis in the face of a large excess capacity in the country make competition exceptionally keen.

Financial structure. As is the case with other American industries that consist of large production units, the sugar refining plants have been built or acquired from previous owners by corporations that now own and operate them. Corporate investments, including bonds, vary from about $3,000,000 in companies having a single small refinery to more than $100,000,000 in the American Sugar Refining Company, with its five refineries, cooperage plants, steamships, Cuban properties, and other investments Besides the investment in plant and equipment, the working capital required for a sugar refining enterprise is necessarily large. Much money is tied up at times in raw and refined sugar inventories and miscellaneous manufacturing and packing supplies.

Labor. Much of the labor employed in the refining process is of the unskilled type, with an admixture of semiskilled men in the "station" or key jobs and a few highly trained hands, such as the sugar boilers. In the maintenance or mechanical department are found skilled mechanics from a number of trades: electricians, pipefitters, boilermakers, tinsmiths, arpenters, masons, machinists, and others. Women are employed only n packing operations.

The refineries employ about 18,000 men and women, whose wages and alaries total over $25,000,000 annually. The minimum wage for comion labor is 65 cents or more per hour in refineries producing about 70 er cent of all domestically refined cane sugar. Most of the refineries re unionized.

Organization of refineries. The organization of refineries varies omewhat according to individual ideas, but in general there is a superinendent or manager who directs the manifold activities of the entire ant. His first lieutenants, to cite a typical case, are the first assistant iperintendent, who directly supervises the refining process, and the ant engineer, whose jurisdiction covers maintenance of plant, improveents to buildings and equipment, the generation and transmission of eam and power, and the purchase of machinery and supplies. Departents not immediately identified with either process or engineering may supervised by heads who report directly to the refinery superintendent.

Such are the dock (receiving and handling of raw sugar), the laboratory (chemical control), and the packing and delivery (of refined products) departments.

Since the process of refining is a continuous one, there must be two night superintendents to cover the period from, say, 5 P.M. to 8 A.M. A skeleton mechanical force is carried at night for oiling and to meet

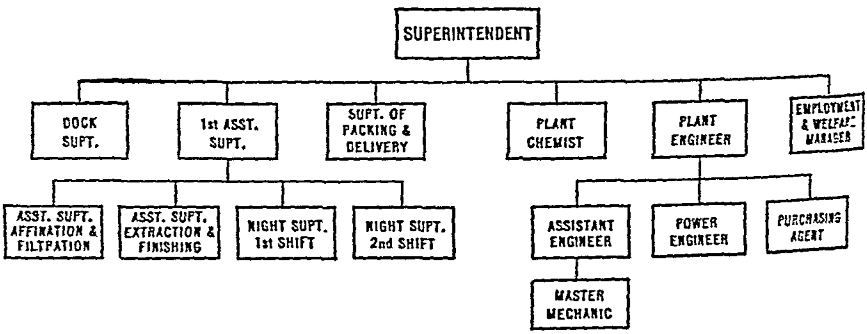


Fig. 1. A typical refinery organization.

emergencies. In so far as possible, all repairs are made in daytime, and an effort is made to leave all equipment at the close of the day in such condition as to require minimum attention during the night. Sufficient raw sugar to last through the night is dumped during the day into large bins, whence it can be withdrawn without labor. Refined sugar manufactured at night is likewise stored in bins to be packed the following day. In Figure 1 is shown a supervisory organization such as that just outlined.

Import duties. The present duty on 96-degree raw sugar imported from Cuba, as fixed by a reciprocal trade treaty, is .90 cents per pound. All other foreign sugar pays 1.875 cents per pound. It is provided however, that, if the existing marketing quota shall be suspended, the duty on Cuban sugar shall revert to 1.50 cents per pound, which was the rate in effect when the Cuban treaty was negotiated in 1934. In fact, the 1.50-cent duty was again in effect for more than 3 months at the close of 1939 because of a temporary suspension of quotas.

Duty differentials apply to sugars testing above or below 96 degrees, but there is no additional duty on refined sugar; in fact, the duty on 100 pounds of refined sugar is slightly less than the duty on the quantity of 96-degree raw sugar (107 pounds) required to produce 100 pounds of refined. Several earlier tariff acts provided for the assessment of additional duty on sugar lighter than a certain color standard known as "Number 16 Dutch Standard," but this provision was omitted in the tariff act of 1913 and has not since been restored. The failure to protect refined sugar encouraged the production in Cuba and importation into the United States of direct-consumption white sugars, which, finding a ready market at prices slightly lower than American refined, have encroached upon the latter in ever-increasing quantities from the beginning of refining in

Cuba, in 1925, until production was finally restricted somewhat by the quota system in 1934.

Refiner's margin of profit. The difference between the basic price of refined sugar, less cash discount and excise tax, and the duty-paid price of 96-degree raw is termed the refiner's margin. This margin, which, for the great bulk of refiners' sales, is less than 1 cent per pound, must cover the cost of refining, including depreciation and overhead and the expenses of sales and administration, before a profit can be realized. Furthermore, since only about 93½ pounds of refined sugar are obtainable from 100 pounds of 96-degree raw sugar, the shrinkage amounts to 6½ per cent of the value of the raw. With raw sugars selling at 3.00 cents, duty-paid, for instance, the value of this shrinkage would be 0.195 cents per pound, which would be offset only in small part by the value of the molasses obtained as a by-product.

The average margin, based on the daily quotations for raw and refined sugar during the 5-year period ending with the year 1939, was 1.06 cents per pound. This is an "apparent margin," however, and does not represent the real, working margin of the refiner. The reason for this is that, while the daily quotations of the raw sugar market over a long period of time may fairly represent the average price paid by refiners for their raw sugars during such a period, since purchases are generally made at frequent and rather regular intervals, the same is not the case with the selling of refined sugar. Probably 85 to 90 per cent of the volume of refiners' sales are made on a few "market moves" during the year. Usually on the basis of a strong tone in the raw sugar market, one of the refining companies will announce an advance in price to take effect a day or two later. Most or all of the other refiners, having to pay more for their raw sugars, will follow with similar announcements, and the trade will then rush in to purchase, say, 30 days' supply of refined sugar before the advance takes effect. After such an advance, a period of several weeks may elapse during which daily quotations of refined sugar range higher than the "move" price, but with new sales insignificant in volume. The United States Cane Sugar Refiners Association has estimated that the actual margin has averaged only 0.84 cents per pound over the last 6 years.

Sugar-control legislation. In 1934, through the enactment of the Jones-Costigan amendment to the Agricultural Adjustment Act, sugar became a basic agricultural commodity within the meaning of the act. Marketing quotas were established for all domestic and territorial areas producing cane or beet sugar, as well as for foreign countries. A processing tax of ½ cent per pound, raw value (0.535 cents per pound, refined value) was levied for the benefit of the growers as compensation for reducing their crops. The processing tax and benefit payments to growers were nullified by the United States Supreme Court decision early in 1936, but the quota system remained in effect. In 1937 a new sugar bill was enacted which continued the quota system and established an excise tax at the same rate as the former processing tax but payable into general Treasury funds. The 1937 act provides, however, for the

payment by the Government of sums to growers for the purpose of "soil conservation." The general result is therefore the same as that achieved by the earlier processing tax.

Under the Sugar Act of 1937, the Secretary of Agriculture determines in December of each year the consumption requirements of the continental United States for the ensuing year and fixes the total sugar quota accordingly. In making such a determination, the Secretary is required to use as a basis the quantity of direct-consumption sugar distributed for consumption. as indicated by official statistics of the Department of Agriculture. during the 12-month period ending October 31 next preceding. making allowances for a deficiency or surplus in inventories of sugar and changes in consumption, as computed from statistics published by Government agencies. The total quota, which, it is provided, shall be not less than the quantity of sugar required to give consumers in the continental United States a per capita consumption equal to that of 1935-1936 (changed by the Ellender Bill to 1937-1938), may be revised from time to time during the year. based upon a redetermination of consumption requirements or in order to prevent excessive prices to consumers as a result of regulation under the act, or, in case of a national emergency. quotas may be suspended altogether. The total quota is divided between domestic and foreign producing areas, allotting 55.59 per cent thereof to the domestic areas (domestic beet, mainland cane, Hawaii, Puerto Rico, and the Virgin Islands), and 44.41 per cent to the foreign areas, including the Philippine Islands, provided that the domestic quota shall be not less than 3,715,000 short tons, raw value, and that in no case the quota for the Philippines shall be less than the duty-free quota established under the Philippine Independence Act, namely, 850,000 long tons. If. however, the total sugar quota should be less than 6,682,670 short tons then the foreign quota, instead of being 44.41 per cent thereof, would be the quantity by which the total quota exceeds 3,715,000 short tons. The domestic and foreign quotas are allotted as follows:

TABLE IV

DOMESTIC AND FOREIGN SUGAR QUOTAS

Domestic Quota (55.59 Per Cent of Total)			*Foreign and Philippine Quota (44.41 Per Cent of Total)*		
Area	*Percentage of Domestic Quota*	*Percentage of Total Quota*	*Area*	*Percentage of Foreign Quota*	*Percentage of Total Quota*
Domestic beet sugar.	41.72%	23.19%	Philippine Islands.	34.70%	15.41%
Mainland cane sugar.	11.31	6.29	Cuba	64.41	28.60
Hawaii.	25.25	14.04	Other foreign. . . .	.89	[illegible]
Puerto Rico . .	21.48	11.94			
Virgin Islands. .	.24	.13			
Total. . .	100.00%	55.59%	Total. . . .	100.00%	44.41%

Provision is made for revisions of domestic and foreign quotas in the event that any area is unable to market its allotment.

One of the effects of sugar-control legislation is that the expansion of production in Puerto Rico, Hawaii, and the Philippines, which had been rapid over a period of years under a high protective tariff and at the expense of Cuba, has been checked; and all of these producing areas, as well as Cuba and the United States beet- and cane-sugar producing areas, are permitted to market only their allotted shares of the total sugar consumed annually in the United States. Another effect is that, since the quotas are fixed by the Secretary of Agriculture and may be increased or decreased by him from time to time or suspended altogether under certain circumstances, as was done to stem a consumers' panic that followed the outbreak of the war in Europe in September, 1939, the Secretary of Agriculture may exercise a very positive control over the price of sugar in the United States. Sharp changes in price have, in fact, immediately followed several announcements and proclamations by the Secretary concerning consumption estimates and quotas.

The refiners have received but modest aid from the quota system. Their pressing problem was tropical or "offshore" refined sugar. In the absence of tariff protection for refined sugar, the imports of Cuban refined had reached nearly 500,000 tons annually, and our own insular territories were also sending considerable quantities of refined sugar to the mainland. The Jones-Costigan Act scaled down Cuba's refined exports to the United States slightly but allowed as much as ever to come in from Puerto Rico, Hawaii, and the Philippines. Under the Sugar Act of 1937, the quantity of refined sugar allowed to enter this country annually from Cuba was reduced to 350,467 short tons refined value, as compared with 432,311 short tons refined value in 1936, while Puerto Rico and Hawaii were permitted to send in as much sugar as their former quotas. By the terms of the 1937 act, the quota plan in general and its limitations on Cuban refined sugar were to continue until December 31, 1940, but its restrictions on Puerto Rico and Hawaiian refined sugar ended on February 29, 1940. The Cummings Act, however, signed by President Roosevelt on October 16, 1940, continues the sugar quotas through the year 1941, with restoration of the limitations on Puerto Rican and Hawaiian refined sugars.

Economic position of refiners.[5] It would appear that the cane-sugar refining industry of the United States is in a precarious position and that it may even find itself in danger of extinction unless protection by Government action from offshore refiners who employ low-cost, tropical labor shall be continued.

There is ample reason for maintaining the mainland refining industry. Not only does this more than 2-century-old industry supply jobs to

[5] This subject is fully and most adequately treated in an article entitled "Does the United States Want to Keep Its Cane Sugar Refining Industry?" by H. Beach Carpenter, General Counsel of The American Sugar Refining Company, in the *Wharton Review of Finance and Commerce* (University of Pennsylvania) for October, 1938

some 18,000 persons directly and to many more in allied industries indirectly, but the refineries of today are modern and efficient. They are adequate to supply the country's requirements in any emergency, as they have ever been, whereas tropical refined sugar cannot be so relied upon. Our refineries, located along the seaboard, can draw their raw sugar supplies, quotas permitting, from available sources throughout the world. If, however, the local cane crop on which each tropical refining area depends should for any reason fail, that area might be unable to supply sugar urgently needed here. In time of war moreover, it might be difficult, if not impossible, to assure safe passage of sugar from insular refining areas in either the Atlantic or the Pacific, but copious supplies of raw sugar could be obtained from world sources and brought here unless both our east and west coasts were successfully blockaded. It is significant that every other important country protects its home cane-sugar refining industry and that even those who have tropical possessions producing cane sugar, like Great Britain, Holland, Portugal, and Japan, do not permit such possessions to strangle their homeland refineries.

The United States Cane Sugar Refiners' Association. This association, of which most of the 13 sugar refining companies previously mentioned are members, maintains offices in New York and Washington, D. C. Its chief purpose is to inform the public of the essential character of the cane-sugar refining industry in the national economy and of the problems with which the industry is faced. In this activity the labor organizations of the industry render important assistance. Chambers of commerce and local governments of cities in which refineries are located are also being very helpful.

Through its Washington office the association follows closely all legislative and administrative developments connected with Government control of sugar, and furnishes pertinent information to interested members of the legislative and executive branches of the Government.

New refining processes. In recent years a number of small refineries have been erected in the United States which make use of activated carbon or, more recently, of chemical agents instead of boneblack for decolorizing purposes. Other steps in the process are the same as in a boneblack refinery, but the carbon and chemical refineries generally produce only fine granulated sugar, making none of the special coarse-grained sugars, tablet sugars, or soft sugars. The first cost of such a refinery is materially less than that of a boneblack refinery of equal capacity, but studies have indicated that its operating cost may be as high or higher than that of a boneblack refinery when producing fine granulated. The carbon and chemical process sugars, however, usually sell lower than the standard refiners' basis price.

Much, though not all, of the refined sugar that comes into this country from Cuba, Puerto Rico, and Hawaii is made by the carbon and chemical processes. Another grade of direct consumption sugar that comes in from the island areas is known as "*turbinados.*" The name originally meant simply sugar that was spun in a centrifugal machine, comparable to the term "centrifugals" today, but it now applies only to sugar made

usually from well-clarified juice, washed in the centrifugal machines, and dried.

Sugar syrup. Another rather recent development is refined sugar in liquid form, generally known as "sugar syrup." This syrup is made in the refinery by evaporating the decolorized liquor from the char filters to about 67 per cent solid content, which is as dense as a sugar solution can be made without having crystals form on cooling; or by dissolving to the same density off-color sugar, which would have to be reprocessed anyway, and decolorizing the solution. Sometimes a portion of the sugar is inverted by heat with a trace of an acid (subsequently neutralized), in which case the syrup can be concentrated to a higher density without crystallization. Sugar syrups are widely used in the New York area by ice-cream manufacturers, bottlers of carbonated beverages, preservers, manufacturing confectioners, and others, and are gradually spreading to other areas where refineries are located. The food or beverage manufacturer using syrup effects a saving, because the refiner, eliminating the bag or barrel and the cost of several steps in the refining operation, can price it lower than dry sugar. The manufacturer also saves handling charges on sugar, the syrup being unloaded from a tank truck into his storage tank by pumping and then pumped to any part of the plant. It may be necessary, as in the case of candy making, to evaporate an additional quantity of water when using syrup in place of sugar, but the additional cost attendant thereon is small in relation to the gross saving that results from the use of syrup. Preservers who can use the heavier partially inverted syrup can so reduce the quantity of water to be evaporated in their process.

For about 2 years after the sugar-quota system was established there was no quota on sugar syrup, and importations thereof from Cuba increased very rapidly, reaching over 14,000,000 gallons in 1936. Since nonquota sugar or syrup produced in Cuba has always sold at a much lower price than the United States quota product, the importation of syrup here was a most attractive proposition. The Government finally recognized that syrup was being substituted directly for sugar in this country and established a syrup quota of about 8,000,000 gallons annually for Cuban syrup, bringing this material approximately within the price range of sugar. San Domingo, which had also been sending syrup here, has a yearly quota of about 800,000 gallons.

Sugar as a food. It is universally recognized that carbohydrates form an essential element of the human diet and that the one of lowest cost and most quickly assimilable is sugar.

Dextrose (refined corn sugar), another carbohydrate of the sugar family that has been offered as a substitute for sugar in recent years, is commonly rated as two thirds as sweet as sugar for the variety containing water of crystallization to three fourths as sweet for the anhydrous variety. The calorific or energy value of the former is 12 to 13 per cent less, and that of the anhydrous variety 5 per cent less than the energy value of sugar. Dextrose is also less soluble in water than is sugar.

The ready solubility and pleasant sweet taste of sugar render it

adaptable to many food manufacturing purposes, such as the sweetening of beverages and the manufacture of confectionery. In the latter the ability of sugar to assume an amorphous form (hard candy) and to form in exceedingly minute crystals (fondant), as well as its sweetness and solubility, determines its value. In fruit preserves sugar constitutes the preserving as well as the sweetening agent; in bread it is fermented by the yeast in the leavening process; and it is also the sweetening agent of sweet doughs for cakes Much sugar is used in ice cream, pastries, jelly powders, and a great variety of other food products.

The household uses of sugar as a food are too familiar to require enumeration. It may not be amiss, however, to call attention to the grades of sugar most suitable for specific purposes. Granulated sugar should be used for general sweetening purposes in the kitchen; light-brown sugar for sugar cookies, coffee cake, doughnuts, sauces, and fudges, and the old-fashioned dark-brown sugar for gingerbread, baked ham, baked beans, baked apples, candied sweet potatoes, mincemeat, and other comestibles. At the dining table, cube or tablet sugar for sweetening hot beverages, a coarse powdered sugar for fruits, cereals, and iced beverages, and light-brown sugar for pancakes and waffles are the proper sugars. The yellow and brown sugars offered by refiners in household packages, as well as in larger units to manufacturers, are refined sugars from which the molasses of the refining process has been only partially separated. They contain mineral substances, which recommend them to persons seeking to increase the mineral content of their diet.

Raw sugar should not be eaten, as it is not generally prepared for direct human consumption and may contain sand, dirt, and harmful bacteria, all of which the refining process removes. Again, raw sugar may be handled and packed without the care and sanitary protection given the products of our refineries. This same may be true also of offshore refined sugar, packed, as it generally is, in 100-pound bags by native labor. The cleanest and safest supplies of sugar can be assured by purchasing it in packages that bear the trade-mark brand of a United States refiner.

Our Beet Sugar Industry of Today

Sugar-beet culture. The sugar beet (*beta vulgaris*), a white variety of the vegetable, averages in this country about 16 per cent in sugar content. The roots weigh from 1 to 2 pounds, and the foliage grows to a height of about 14 inches above the ground. The average yield per acre in this country is about 10 tons of beets, furnishing 1⅓ tons of sugar. Warm, bright days and cool nights and about 16 inches of rainfall, or irrigation, are required to attain a good sugar content. Deep plowing and laborious cultivation of the growing plants are needed. The seed is planted in the spring, and the beets are harvested in autumn and early winter. The manufacturing campaign lasts about 100 days. The factories are idle during the remainder of the year.

Investment, volume, and distribution. The investment in our Amer-

ican beet sugar industry is said to exceed $220,000,000. There are 100 factories located in 17 states, with a combined daily slicing capacity of about 128,000 tons of beets. The Rocky Mountain area takes the lead in production, although California produces more than any other single state. Michigan and Nebraska also stand in important positions on the list of states. In the campaign of 1939-1940, 86 factories were in operation. These factories made more than 1,600,000 short tons of sugar. The following table shows the geographical distribution of beet sugar factories operated, the acreage harvested, the amount of beets sliced, and the amount of beet sugar produced in 1939-1940.

TABLE V

UNITED STATES BEET SUGAR PRODUCTION IN 1939-1940[6]

State	*Number of Factories Operated*	*Number of Factories Closed*	*Acreage Harvested*	*Beets Sliced (in short tons)*	*Beet Sugar Produced (in short tons)*
Ohio ...	4	1	47,000	363,000	42,000
Michigan	13	3	120,000	1,033,000	162,000
Nebraska.......	7	—	69,000	790,000	106,000
Montana.......	5	—	74,000	894,000	140,000
Idaho	8	—	73,000	985,000	127,000
Wyoming . .	5	—	49,000	539,000	92,000
Colorado ..	17	2	145,000	1,543,000	262,000
Utah .	7	4	53,000	683,000	100,000
California .	10	1	166,000	2,699,000	451,000
Other states	10	3	121,000	1,244,000	159,000
Total	86	14	917,000	10,773,000	1,641,000

Process of manufacture. Beets are delivered by the grower to the factory's beet sheds in wagons or motor trucks, or in freight cars. The load is weighed and the beets are dumped down an incline. They pass over a screen which returns the loose dirt, small stones, and such to the vehicle, which is then weighed again. The difference represents the gross weight of the beets delivered. The beets are then sampled, and the sample beets are weighed, topped, and carefully brushed to remove adhering dirt. The cleaned sample is again weighed to determine the percentage tare, which is applied to the gross weight of the beets delivered in order to obtain the net weight. The sample is then sent to the laboratory for determination of its sugar content, as beets are generally paid for on a basis of net weight, with possible premiums for high sugar content and for prevailing prices of granulated sugar exceeding a stated amount.

After passing through trash and stone catchers and a washer, the beets are freed from poor specimens and any foreign material which may still be present by hand picking on a conveyor. They are then weighed on automatic scales, and this weight is used in the calculation of factory

[6] From Willett and Gray, *Facts About Sugar*, and other sources.

yield. In the slicer the beets are reduced to long thin slivers, called "cosettes." The cosettes are dropped into large tanks known as "diffusion cells," which are grouped in either circular or straight-line formation. Diffusion batteries range, in general, from 9 to 14 cells. Hot water is percolated through the cosettes to extract the sugar and flows from cell to cell of the battery in regular order, so that, as each cell is filled with cosettes, it gets water that has already passed in series through the preceding, filled cells and is therefore rich in sugar, while the fresh water is fed to the cell which contains the most nearly exhausted cosettes and is therefore next to be taken off and emptied.

The solution running always from the last filled cell to the factory is called "diffusion juice" and contains about 14 per cent solids. After being measured, it passes through a heater to a tall tank, where it is treated with lime and carbon dioxide gas, forming a precipitate of lime carbonate. This operation is called "first carbonation." If the carbonation is carried too far, however, some of the precipitate will redissolve, so the latter is removed by filtration at the right point before complete saturation and the clear juice is separately subjected to a "second carbonation." The precipitate from the second carbonation is likewise filtered off, and the juice is thereafter bleached with sulphur dioxide gas in a process known as "sulphitation." Again a precipitate is formed and removed by filtration. The next step is concentration in a multiple-effect evaporator to about 60 per cent solids.

The thick juice is then sulphered, and the precipitate formed is filtered off. The juice, after its four chemical treatments, consisting of two carbonations and two sulphitations as described, is freed from considerable of its impurities and is now ready for crystallization. The large amounts of lime required are obtained by burning limestone mixed with coke; this operation supplies also the carbon dioxide needed for carbonation. Sulphur dioxide is generated by burning crude or roll sulphur, or is purchased from chemical manufacturers.

Crystallization takes place in vacuum pans, as in a cane sugar refinery; the boiling process is practically identical with refining practice, except that only one crop of white crystals is obtained. Also substantially the same as in cane sugar work are the centrifugal separation and drying of the sugar, and the working down of the afterproducts with blackstrap molasses left as the residual product of sugar extraction. Remelt sugars, generally called "raws" in a beet house, are returned to the thick juice either before or after sulphitation.

Comparison of beet with cane products. Granulated beet sugar, when properly manufactured, is not noticeably distinguishable from granulated cane sugar. Beet sugar molasses is not edible because of its unpleasant odor and flavor and a high mineral content. When mixed with dried exhausted beet pulp from the diffusion batteries, however, it makes an excellent feed for cattle. The beet tops, too, are used for fodder. Beet molasses is also of value for the production of alcohol. It contains about 50 per cent of sugar not recoverable by crystallization

Utilization of beet sugar molasses. Many beet sugar factories, instead of selling their molasses, extract a considerable quantity of the sugar contained therein by means of the so-called "Steffen process." *This process involves the formation of an insoluble lime sugar compound* in a dilute, refrigerated solution of the molasses. The "saccharate," as this compound is called, is separated by press filtration and added to the diffusion juice in lieu of milk of lime. In contact with the hot juice, the saccharate is decomposed. Its sugar component passes into solution, while the lime set free forms the necessary supply for the carbonation process. When the Steffen process is used, the molasses turned out by the factory gradually becomes contaminated by certain impurities returned to the process with the saccharate, and periodically a quantity of molasses has to be discarded.

This discard or by-product molasses is generally sold, but The Great Western Sugar Company in 1925 installed a process for the recovery of sugar from the discard molasses of its 21 factories located in Colorado, Nebraska, Wyoming, and Montana. This, the *ne plus ultra* in sugar recovery, is the "barium process." Barium hydrate, a substance closely related chemically to lime, forms a saccharate of higher purity and lesser solubility than lime saccharate. The barium process is housed in a separate factory, centrally located at Johnstown, Colorado. The mineral witherite, which is barium carbonate, is there converted into barium hydrate. This is added to a dilute solution of molasses. The saccharate thus formed is separated by filtration, suspended in water, and decomposed by saturating with carbon dioxide gas. The combined sugar is thus liberated, passing into solution in a fairly pure form, while insoluble barium carbonate is precipitated and filtered off. The sugar solution is further purified by chemical treatment and by boneblack filtration, after which it is evaporated and crystallized in the usual manner. The barium, a valuable substance, is recovered from the carbonate cake for re-use in the form of barium hydrate. This is accomplished by subjecting the filter cake to a high temperature in a rotary kiln, admixed with some barium silicate to prevent fusion. The resulting clinker is leached out with water in a wet grinding process, followed by sedimentation. Barium hydrate is formed, passes into solution, and is purified by crystallization. When again dissolved in water, it is ready for use. The barium recovery feature is thus a complicated and expensive adjunct to the process and is further made difficult by the fact that the kiln clinker has a cementlike nature. The sludges formed therefrom must be handled with great dispatch to prevent their hardening.

That the Johnstown plant has surmounted such difficulties in recovery as have sealed the fate of some barium plants in other countries is evidenced by the fact that it has been kept in operation for some 15 years, working up throughout the year molasses that has been accumulated during the sugar factories' short campaign. The sugar manufactured must be and is entirely free from barium compounds, which are poisonous to the human system.

Domestic and Insular Cane Sugar

Increased in island territories and the quota system. The production of raw cane sugar in Hawaii, Puerto Rico, and the Philippine Islands greatly increased between the close of the War of 1914 to 1918 and the adoption of the quota system by our Government in 1934, especially in the two last-named possessions. This was due in large measure to the development of superior strains of sugar cane and to the stimulus of substantial and successively increased sugar tariffs, and resulted in the exclusion of a corresponding quantity of duty-paying Cuban sugar from United States markets. With Cuba, the world's second largest sugar producer, desperately competing for as great a share as possible of our purchases, the price of sugar naturally fell to low levels, so that even with the then existing tariff protection of 2 cents per pound the sugar industries of Hawaii and Puerto Rico, having higher manufacturing costs than Cuba, were scarcely functioning on an economic basis. The same was true of our continental beet- and cane-sugar producing industries, and the Philippines too were affected In Cuba distress became most acute. Selling in the face of the 2-cent protective duty, the Cubans were forced at one time to accept little more than ½ cent per pound, including cost of production and freight to New York, for their raw sugar.

This substantially was the sugar situation when, in 1934, the quota system was adopted. Marketing quotas within the United States were established approximately on an historical basis; that is, the production of each area in the years immediately preceding was considered in fixing its quota. In some cases, as explained previously, total sugar quotas have been made to include a certain quantity of sugar in the refined form. The quotas have tended to increase sugar prices over what these ran for some time previous to the inauguration of the quota system, but there has been much complaint over its management. It is claimed that one of the main purposes of the system—namely, as expressed in the Sugar Act of 1937, "to protect the welfare . . . of those engaged in the domestic sugar-producing industry"—has still not been given due regard. At any rate, it is apparent that under the quota system the sugar-producing industries of continental United States and of Cuba have not been maintained in a flourishing condition, to say the least. Cuba is mentioned here because probably two thirds to three fourths of its sugar industry, which represents an investment of some $1,250,000,000, is of United States ownership and because it was manifestly intended that Cuba should benefit from the quota system.

The tabulation on the following page shows the sources of our consumption of cane sugar for the years 1935 to 1939.

Sugar-cane culture. The planting and harvesting of sugar cane varies as to season in different parts of the world. In the West Indies the grinding season is from December to June; in Hawaii and the Philippines, from November to July; in Louisiana, from October to January. Methods of cultivation and manufacture are, on the whole, similar in

TABLE VI

CONSUMPTION OF CANE SUGAR IN THE UNITED STATES, CLASSIFIED AS TO ORIGIN[7]

(Refined and/or Consumption Value)

(In Tons of 2,240 Pounds)

State	*1939*	*1938*	*1937*	*1936*	*1935*
Louisiana and Florida ..	517,981	459,382	414,212	373,099	258,593
Hawaii	743,426	741,996	816,303	770,299	826,137
Puerto Rico.	788,175	719,732	763,500	730,154	682,048
Philippine Islands.. ...	793,558	806,014	813,303	775,215	749,161
Virgin Islands	4,722	3,278	6,645	3,122	2,055
Cuba	1,402,886	1,677,535	1,821,4[illegible]5	1,642,990	1,639,450
Total..... . .	4,250,748	4,407,937	4,635,378	4,291,879	4,157,444

various regions, and the following description of operations in Cuba will furnish a general idea of the methods commonly used.

The first step in the work of developing a cane plantation is clearing off the timber. Much of this wood, mahogany and cedar, is very valuable, and care must be taken in the foresting to see that its lumber value is preserved.

After lumbering operations are completed, the brush and creepers are cleared by burning. The burning does not entirely clear the land, however, and the partially burnt stumps and logs are left to disintegrate under the warmth and moisture of a few wet seasons. And yet it is not necessary to wait for this in order to make the first planting, for after the cane cuttings have been planted, their growth is so dense and rapid as to kill effectually any further development of underbrush.

Cane fields used for commercial production are planted with cuttings, each about a foot long and containing two or three seed buds. The planting, owing to the rough character of the soil, is naturally very primitive. A man drops the cuttings every 3 or 4 feet. Another man follows him and, making a hole with a pickax, thrusts the sugar cane cutting into this hole, tamping the earth above it with his feet. So luxuriant is the growth of the vegetation in tropical climates that this method is sufficient to produce a plant with several shoots, which soon form a clump, or stool, of cane. One planting on virgin soil such as this is sufficient to produce crops for 10 to 15 years. New plants termed "ratoons" spring up from the stubble after each harvesting.

The numerous stems sent up are very similar in appearance to our Indian maize and often attain a height of from 15 to 18 feet. The stems are thick and unbranched. The leaves, 3 feet or more in length, are broad and flat. The plant matures with the approach of the dry season. When the cane is harvested, the stalks are cut by hand.

Harvesting and transportation. Although those interested in plantation operations have sought to produce a machine that will cut cane as

[7] Willett and Gray, *Facts About Sugar.*

our mechanical mowers cut grass and although many such machines have been produced, so far none has come into general use. An expert workman in the field can, with his heavy machete or knife, cut and load 6 tons of cane a day. In cutting, the leaves are stripped from the stalks, which are then loaded into ox carts, the leaves serving as fodder for the oxen. Within easy hauling distance from each field is located a railroad siding and loading station, and thither the creaking ox carts wend their way. These loading stations are furnished with cranes which are able at one time to lift the full load from the cart and deposit it in the waiting railroad car.

Mill-owned locomotives then haul the loaded cars to the "centrale," where unique fireless locomotives, which run 8 hours or more on one charge of steam taken from the mill, switch them on to tilting tables. The cars have hinged sides, so that when these tilting tables are elevated to a sufficient angle the sugar-cane load slides from the car on to a slatted conveyor, which carries the sugar-cane stalks first to the cane knives, where the stalks are cut into short pieces, and next to the crushers, where the cane is shredded. These last consist of two cylinders with interlocking ridges, which rupture the cane as it passes through by twisting. This process is not primarily intended to press out the juice, but the cane is shredded and prepared for subsequent juice extraction by the mills. Each mill consists of three rollers, and a series of mills from four to seven in number is known as a "tandem."

Sugar manufacture. The cane is now passed on to these other heavy horizontal steel rollers or mills, which, exercising a tremendous pressure, cause a rupture of the sugar-cane cells and press out the juice. As the cane enters the last two mills, sprays of water facilitate the extraction of the remaining juice. The pulp that is left, known as "bagasse," is conveyed to the boilers and provides the bulk of the fuel necessary to operate the mill. The sugar-cane juice, constituting about 80 per cent of the weight of the cane, is now ready for the clarification process. The juice is first raised to a temperature of about 210 to 220 degrees F. and flows into large tanks, where sufficient lime is added to neutralize the destructive acids present, coagulate the albumen, and at the same time purify the juice. Residue from this process is passed through filter presses to remove the mechanically suspended impurities.

Concentration of the juice into syrup now takes place in the evaporators, and the granulation of the syrup thus produced is effected in the vacuum pans, where, through further elimination of water, crystallization takes place. The sugar, which is still soft and damp owing to the fact that molasses is still present, goes to the centrifugal machines. The basket is spun at a speed of from 1,000 to 1,200 revolutions per minute, until a considerable amount of the molasses is thrown off. The sugar thus produced is known as "centrifugal sugar." Practically all the raw sugar used in the United States is of this grade. Packed in bags, the raw sugar is ready for shipment to the nearest seaport, where it is loaded into vessels to begin its long water journey to the cane sugar refineries.

Status of Louisiana and Florida. Louisiana, although it can scarcely

ever become a major source of supply, is decidedly looking up from the depths of the year 1926, when its production sank to little more than 40,000 tons. The rescuer is a new, disease-resisting strain of the sugar cane that was developed some years ago in the Experiment Station of East Java (Proefstation Oest Java). Taking its name from the Station and a number assigned in the course of culture experiments, this cane is known throughout the sugar world as P.O.J.234. It is peculiarly resistant to the destructive mosaic disease of sugar cane, which ravished the cane fields of Louisiana for several years with a cumulative effect that is characteristic of this disease. The P.O.J. cane has been highly successful in Louisiana, as in other cane-growing lands, and has literally saved the state's venerable industry. According to the Government Census figures for 1929, the yield of P.O.J. cane in Louisiana was 19.3 tons per acre, as against 9.3 tons for native cane.

In recent years Florida has become a significant factor in the domestic sugar picture, reaching 88,000 tons in 1939-1940, a larger output being prevented only by quota restrictions.

Effect of overproduction. The enormous expansion of cane sugar production in many countries, but most notably in Cuba and Java, during and after the War of 1914 to 1918, and the recovery of beet sugar in Europe following its serious setback occasioned by that war have caused world production to increase faster than world consumption. Furthermore, expansion in many countries has been fostered by tariff legislation or similar artificial means. Because of this much of the world's sugar, produced at a high cost, is marketed at a profit, while low-cost producers in other regions are compelled to sacrifice their product, often at a loss.

As a result of these world conditions, sugar prices in the United States descended to prewar levels, notwithstanding three successive increases in tariff duty aggregating approximately a cent per pound; in fact, in 1933, raw sugar sold in New York (cost and freight, Cuba) as low as 0.57 cents per pound, the lowest price ever recorded. It is interesting here to note that, on the basis of this price, the import duty on Cuban sugar was approximately 350 per cent and on other foreign sugars 440 per cent ad valorem.

Sugar-control plans. Cuba had tried at various times, with but little success, to bolster the price of sugar both by crop restriction and by governmental control of sales and shipments. Restriction in Cuba merely stimulated production in other countries. Not only in Cuba but also in Java and other exporting countries stocks continued to mount, to the dismay of all concerned. In 1931 Cuban interests, under the leadership of Thomas L. Chadbourne, a New York attorney, were instrumental in bringing about an agreement between some of the larger sugar-exporting countries, whereby these countries were to limit the exports to predetermined quantities for a period of 5 years, segregating current stocks and restricting production as might be necessary to fit the requirements of the plan. The signatories to this agreement, seven in number, were Cuba, Java, Germany, Czechoslovakia, Poland, Belgium, and Hungary. These countries represented the great bulk of

sugar that passed at the time from one nation to the other the world over, but vast production areas were left out, notably the British Empire, Russia, Japan, Puerto Rico, Hawaii, the Philippines, and the United States. Although the five-year plan did not come up to expectations, increased production being invited and actually taking place within some of the areas not covered, Cuba—but not the other signatories—was benefited somewhat by the quota system established in 1934 by the United States

Finally in 1937, in London, a much more comprehensive international convention, now known as "The International Sugar Agreement," was signed by 21 sugar-producing countries, this time including the United States and Great Britain, both large importers of sugar and, together with their possessions, important producers. This time, also, practically all of the important exporting countries signed the agreement, which, by its terms became effective on September 1, 1937, and is to run for a period of 5 years. Exporting countries are committed to limited quotas for exportations to the "free market," which means all but certain excepted exports, as from Cuba to the United States under any import quota allotted by the latter, exports from the Commonwealth of the Philippines to the United States, and certain exports that concern other countries and their colonies. Obligations of the importing countries aim at the maintenance and expansion of the free market. The United States, for instance, undertakes to import as much from the free market as hitherto, and Great Britain agrees to limit her domestic beet sugar production. The agreement provided for the establishment of an International Sugar Council, quartered in London and empowered to watch events and administer the provisions of the agreement.

It is generally conceded in sugar circles that some good has been accomplished by the London agreement. Although at the end of the plan's second year in operation Europe again plunged into war, no nation has up to October, 1940, moved to withdraw from the agreement, as provided therein in the event of its becoming involved in hostilities.

The General Outlook

It would be vain in the present state of world affairs to attempt any prognostication regarding the future of sugar even in this (at present writing) still peaceful nation. The beet sugar fields and factories of France and Belgium have once again come under the destructive hand of war. To what extent they may be devastated, however, is as yet uncertain; and in view of vast potentiality for sugar production in many countries, it is impossible to predict to what extent the United States may be called upon to supply Europe with refined sugar, either during or after the present war. Now that Holland has been subjugated, much may depend on what becomes of her colony Java, with its presently controlled sugar production of 1,500,000 tons and its potential production of some 3,000,000 tons, a considerable proportion of which can be made in the form of "Java whites" for direct consumption. France may find it

necessary or expedient to make up whatever sugar deficiency there may be from the German producing area. Since the beginning of hostilities in September, 1939, the United States has exported significant quantities of refined sugar to some of the countries of Europe, including Norway and Finland before they were involved in hostilities, Switzerland, Greece, Turkey, Palestine and Syria, as these countries found their usual sources of supply cut off because of conservation of supplies by the warring nations or blockade conditions. With the conquest of Norway, however, and the later closing of the Mediterranean to ships of our registry upon Italy's entrance into war, shipments to these areas have been at least temporarily curtailed or suspended. A sizeable market for soft sugars in the United Kingdom had already ceased early in the war. Finally, the capitulation of France, just as she was arranging for considerable supplies of sugar here, has rendered doubtful that country's status as an outlet for our sugars abroad.

Whether and to what extent these markets shall be restored and others created seems uncertain. The area of Europe now under German domination produces an enormous quantity of beet sugar, but as long as the war continues, all of this may be retained within that area, leaving the Mediterranean countries and others to seek their supplies elsewhere, in which case the United States will probably obtain a share of their business. Foreign ships must be used, however, if the present neutrality laws are continued. The United Kingdom at present has ample refining capacity for its needs and can obtain raw sugar from its own colonial possessions, Cuba, and even Java. Destruction by bombing of the refineries in London and Liverpool might, however, change the picture completely.

Looking at the domestic angle of the sugar situation, the difficulties that confront our United States cane-sugar refining industry have been considered in a previous section. The recent enactment of the Cummings Bill, which, during its passage through Congress, gave rise to considerable controversy between various branches of the sugar industry whose interests are more or less conflicting and which was only one of some 20 bills directly bearing upon sugar that have been presented to the 1940 session of Congress settles the sugar question for only a limited time, that is, until the close of the year 1941. Prior to that time the sugar question must inevitably again come up for Congressional action. Whatever may be the outcome of such political considerations and of world changes, as these affect the sugar industry in general, it is safe to say that our own section of that industry here in the United States will feel and respond to every such development, within or without, just as it has done in the past.

TABLE VII

WORLD SUGAR PRODUCTION[8]

(In Tons of 2,240 Pounds)

Cane Sugar:	*1939–1940*	*1938–1939*	*1937–1938*	*1936–1937*	*1935–1936*
United States:					
Louisiana.......	400,814	439,029	357,243	342,423	304,367
Florida	88,000	81,753	50,789	47,515	37,383
Puerto Rico .	982,000	760,678	961,720	889,594	826,817
Hawaiian Islands	850,000	864,636	819,628	821,990	907,474
Virgin Islands .	7,000	5,300	3,503	7,570	3,357
Cuba . ..	2,793,000	2,758,552	3,017,718	3,012,968	2,588,395
Others in America .	3,708,340	3,695,935	3,356,353	3,428,095	3,483,611
Total in America ..	8,829,154	8,605,883	8,566,954	8,550,155	8,151,404
Philippine Islands....	916,070	876,934	945,398	998,060	876,983
British India.......	4,089,960	3,701,908	4,878,164	5,785,410	5,222,046
Java	1,500,000	1,550,738	1,376,868	1,392,146	583,028
Japan.	1,366,000	1,663,750	1,203,018	1,192,690	1,089,884
Total in Asia......	7,872,030	7,793,330	8,403,448	9,368,306	7,771,941
Australia and Polynesia..............	1,020,000	957,322	950,625	935,176	782,898
Africa	1,002,000	1,093,939	1,071,148	996,317	945,035
Europe	13,000	13,124	12,222	15,747	19,619
Total Cane Sugar..	18,736,184	18,463,598	19,004,397	19,865,701	17,670,897
Beet Sugar:					
Europe:					
Germany..........	2,303,812	2,145,141	2,383,659	1,950,527	1,898,239
Czechoslovakia....	519,898	530,474	741,187	709,652	564,798
France......	1,033,200	858,892	975,038	892,103	932,520
Russia and Ukraine.	2,500,000	2,300,000	2,500,000	1,998,943	2,600,000
England	475,000	289,435	377,133	521,944	471,704
Others in Europe...	2,757,959	2,542,816	2,650,371	2,639,740	2,567,142
Total in Europe....	9,589,869	8,666,758	9,627,388	8,712,909	9,034,403
United States	1,462,605	1,485,024	1,147,185	1,167,530	1,052,207
Canada............	75,573	63,883	53,796	67,783	53,508
Total Beet Sugar...	11,128,047	10,215,665	10,828,369	9,948,222	10,140,118
Grand Total—Cane and Beet Sugar... ...	29,864,231	28,679,263	29,832,766	29,813,923	27,811,015

[8] *Ibid.* (January 18, 1940), p. 23; (March 24, 1940), p. 117.

TABLE VIII

UNITED STATES CANE REFINING COMPANIES[9]

Name	Location of Plant	Yearly Capacity in Short Tons
American Sugar Refining Co.	Boston, New York, Philadelphia, Baltimore, and Chalmette, La.	2,362,500
Arbuckle Brothers	Brooklyn, N. Y.	450,000
J. Aron & Company, Inc.	Himalaya, La.	10,000[a]
California & Hawaiian Sugar Refining Corporation, Ltd.	Crockett, Cal.	825,000
Colonial Sugars Company	Gramercy, La.	202,500
Godchaux Sugars, Inc.	Reserve, La.	300,000
Henderson Sugar Refinery	New Orleans, La.	112,500
Imperial Sugar Company	Sugar Land, Texas	240,000
W. J. McCahan Sugar Refining & Molasses Company	Philadelphia, Pa.	300,000
National Sugar Refining Company of New Jersey	Long Island City, N. Y., and Edgewater, N. J.	1,200,000
Pennsylvania Sugar Company	Philadelphia, Pa.	600,000
Revere Sugar Refinery	Boston, Mass.	300,000
Savannah Sugar Refining Corp.	Savannah, Ga.	375,000
Southdown Sugar Refining Co.	Houma, La.	45,000[a]
South Coast Company	Mathews, Franklin, and Houma, La.	45,000[a]
Sterling Sugars, Inc.	Franklin, La.	105,000[a]
Sucrest Corporation	Brooklyn, N. Y.	150,000[a]
Western Sugar Refinery	San Francisco, Cal.	420,000
Total Capacity of United States Refining Industry		8,042,500[b]

[a] Activated carbon or chemical process.
[b] Refined Syrup Sales Corporation, not here included, is now producing both refined sugar and sugar syrup in the former Spreckels Refinery at Yonkers, New York, which had been closed since 1930

[9] *Ibid.*, Vol. XXXIII, p. 39 (1938).

15

The Petroleum Industry

History of Petroleum

Early history. Petroleum has been an article of commerce from the earliest times. Primitive man probably pitched his coracle "within and without," as Noah did the ark, with asphalt from the tar seeps of the Babylonian plain. The bricks of the walls of Babylon were set in an asphalt mortar. Both Herodotus in his *Travels* and Pliny in his *Historia Mundi* describe the early trade in petroleum; it is probable that the Greek fire which enabled the eastern Roman Empire to repel the attacks of the Scythians and the Saracens had a petroleum base which came from the Baku district. Medieval Europe was familiar with *"oleum petrae,"* or rock oil, as a medicine, and the Far East for many centuries traded in oil from the Burmese seepages at Yenangyaung. This commerce, however, was a trade in a rare substance, and very few people came in contact with it Indeed, it was so rare that less than a century ago Lord Playfair, one of England's foremost chemists, stated that prior to 1850 he had never seen a piece of paraffin larger than an ounce in weight. Such petroleum produced prior to 1859 was won from natural seepages by bailing and skimming, or produced as a by-product from brine wells, or extracted from shale or coal. In Galicia, some mining was done for mineral wax (ozocerite). The oil produced was rarely refined to any appreciable extent, and usually the light fractions were discarded.

Oil as a source of light. With the general raising of living standards that took place in the first half of the nineteenth century, the substance that had been looked upon as a chemical curiosity and as a drug began to interest a number of ingenious minds as a possible cheap source of light. The burner invented by the Frenchman Argand in 1784 had shown that such oils could be used for lighting, and in England Dr. James Young developed methods of producing oils from coal and later from oil shale, both of which he patented. These discoveries embraced not only the distillation of oil from shale and coal but also many of the ordinary processes of refining, such as steam distillation and sulphuric-acid treatment of distillates. Under licenses from Young and from an American, Abraham Gesner, the number of coal- and shale-distillation plants increased rapidly in both the United States and England. The demand for the product from these plants was large, as it replaced the more costly

whale and lard oils and gave a better and more dependable light than spermaceti or tallow candles.

Colonel Drake's discovery. The production of petroleum from wells drilled for that purpose began in the United States in 1859. Oil had been produced with brine from salt wells for many years previous, but in the main, because it discolored the salt, it was regarded as a nuisance. In 1857, however, a group of New Haven men formed the Pennsylvania Rock Oil Company, and having received a favorable opinion from Professor Silliman of Yale on the possibilities of crude petroleum as a source of burning oil, sent Colonel Drake to Pennsylvania to drill the first well for oil on Oil Creek, near Titusville. This well came in on August 27,

TABLE I

CRUDE OIL, NATURAL GAS, AND NATURAL-GAS GASOLINE PRODUCTION IN THE UNITED STATES[1]

Year	*Per Cent of Maximum Year*		
	Crude Oil	*Natural Gas*	*Natural-Gas Gasoline*
1915	21.98%	26.11%	2.93%
1916	23.51	31.28	4.63
1917	26.21	33.02	9.75
1918	27.83	29.95	12.65
1919	29.58	30.98	15.74
1920	34.63	33.15	17.22
1921	36.84	27.50	20.14
1922	43.59	31.67	22.65
1923	57.26	41.82	36.54
1924	55.81	47.41	41.81
1925	59.71	49.37	50.48
1926	60.26	54.54	61.02
1927	70.45	60 04	73.47
1928	70.47	65.13	81.21
1929	78.75	79.65	100.00
1930	70.20	80.72	98.96
1931	66.53	70.05	82 01
1932	61.38	64.63	68.22
1933	70.80	64.61	63 57
1934	70.99	73 55	68.74
1935	77.91	79.61	73.96
1936	85.97	90.01	80.42
1937	100.00	100 00	92.47
1938	94.93	93.99	96.55
1939	98 83	(a)	93 82

Actual Quantities for Maximum Year

Crude Oil	— 1937 —	1,279,160,000 Barrels
Natural Gas	— 1937 —	2,407,620,000,000 Cubic Feet
Natural-Gas Gasoline	— 1929 —	2,233,688,000 Gallons

[a] Not available.

[1] Source: United States Bureau of Mines.

1859, at a depth of 69 feet. The primitive drilling rig used by Drake, adapted from rigs used for drilling for brine, was the precursor of the modern cable tool rig, while his use of metal pipe to line the bore hole was the start of modern casing methods. There was an immediate market for the product of Drake's well in the coal-distillation plants which had been erected under the Young and Gesner patents to make kerosene or coal oil for use in lamps.

Beginning of the oil industry in the United States. Here, then, began the first great period of the industry's growth. During the year of the Drake discovery the production was 2,000 barrels, the following year it was 500,000 barrels, and by 1863 it had reached 3,057,000 barrels. The early Pennsylvanian fields yielded an oil peculiarly adapted to the needs of the day in that, with comparatively simple treatment, it yielded burning oils for lamps and lubricants. Development spread rapidly through Pennsylvania and into New York but did not reach the other states until 1876, when oil was first produced commercially in Ohio, West Virginia, and California; however, large quantities of oil were not produced in Ohio until 1886 and in California until 1898. Commercial production was started in Kentucky in 1883, and in Indiana and Illinois in 1889. While the first commercial production of oil in the Mid-Continent began in Kansas in 1889, near the town of Neodesha, yet important production in this general area was not developed until the Corsicana field was opened in Texas in 1896. Discovery of the Spindle Top pool in 1901 opened development on the Gulf Coast. Oklahoma began producing in 1902, and with the discovery of pools in the Bartlesville area in 1904 and the Glenn pool in 1906, it rose rapidly to prominence. Louisiana's first production was in 1898. The New Mexican fields were opened in 1923, while production in Arkansas started with the discovery of the El Dorado field in 1921.

Growth of the petroleum industry. The annual production in the United States, as shown in Tables I and II and in Figure 1, has increased almost continuously since 1859 up to 1929. In 1930, because of the world depression, there was some shrinkage in production; however, it began to increase again in 1933 and has increased practically continuously since then.

Production in countries outside the United States did not become important until 1876, in which year Russia produced 1,300,000 barrels; Rumania reached a production of 1,000,000 barrels a year in 1899, the Polish fields in 1895, and the Japanese fields in 1901. The Netherlands East Indies became a substantial producer in 1895, Mexico in 1907, Persia in 1913, Trinidad in 1916, Argentine and Egypt in 1917, Sarawak in 1918, Venezuela in 1921, Colombia in 1925, Iraq in 1935, and Bahrein in 1936. None of these countries except Russia has challenged the supremacy of the United States in petroleum production. The Russian production exceeded that of the United States in 1898, 1899, 1900, and 1901; in this last year, Russia reached the peak of production until 1928, when a new peak was reached.

The table of world production of petroleum indicates how rapid has been the growth of the industry since 1900.

TABLE III

CRUDE OIL, NATURAL GAS, AND NATURAL-GAS GASOLINE PRICES IN THE UNITED STATES[1]

Year	Crude Oil	Natural Gas	Natural-Gas Gasoline
	Value at wells per barrel	*Value at points of consumption per M cubic feet*	*Value at point of production per gallon*
1915	$ .64	$.161	$.079
1916	1.10	.160	.138
1917	1.56	179	.184
1918	1.98	213	.178
1919	2.01	.216	.183
1920	3 07	.216	.187
1921	1.73	.264	.137
1922	1.61	.291	.144
1923	1.34	.238	.095
1924	1.43	.222	.088
1925	1.68	.223	.107
1926	1.88	.229	.100
1927	1.30	.220	.072
1928	1.17	.232	.077
1929	1.27	.216	.071
1930	1.19	.214	.058
1931	.65	.233	.035
1932	.87	.247	.032
1933	.67	.237	.038
1934	1.00	.223	.039
1935	.97	.224	.043
1936	1.09	.220	.047
1937	1.18	220	.047
1938	1.13	.221	.037
1939	.98[a]	([b])	([b])

[a] Preliminary from *Oil Weekly* (January 29, 1940).
[b] Not available

Early methods of transportation. When oil was first discovered, it was transported in barrels, usually on flatboats, down the rivers, then by rail to refineries, and finally the refined product was sent to the consumer in barrels.

Some of the early fields in Pennsylvania were served by a series of narrow-gauge railroad lines, the oil being run into barrels and loaded on flat cars. Wooden tank cars were first used in 1865 and metal tank cars in 1871.

[1] *Ibid.*

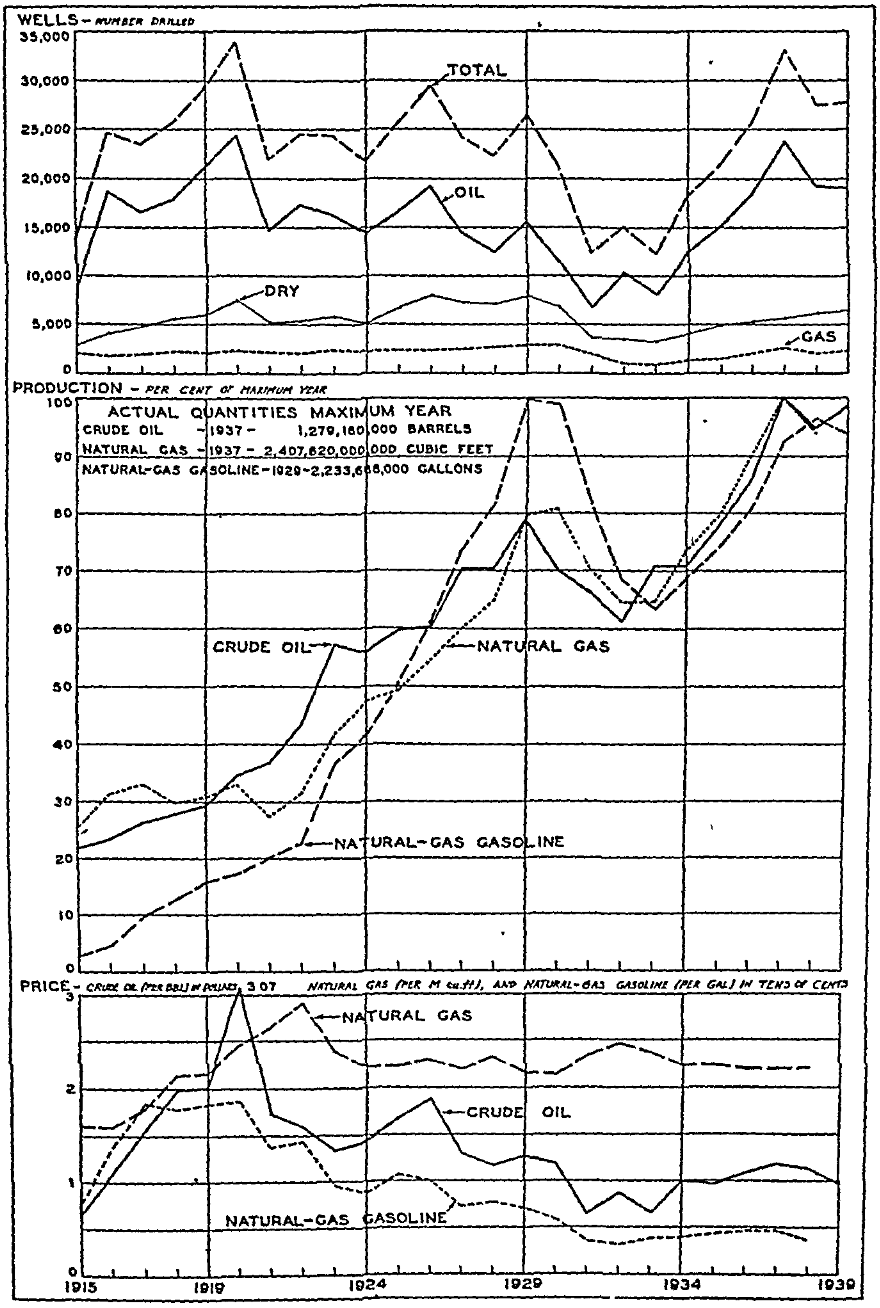


Fig 1. Wells, production, and price of crude oil, natural gas, and natural-gas gasoline in the United States from 1915 to 1939

TABLE IV

DRILLING ACTIVITIES IN THE UNITED STATES[4]

Year	*Number of Wells Drilled*			
	Oil wells	*Gas wells*	*Dry holes*	*Total wells completed*
1915	9,151	2,022	2,981	14,157
1916	18,777	1,803	4,039	24,619
1917	16,590	1,966	4,851	23,407
1918	17,845	2,229	5,613	25,687
1919	21,052	2,135	5,986	29,173
1920	24,273	2,274	7,364	33,911
1921	14,666	2,111	5,160	21,937
1922	17,333	2,024	5,332	24,689
1923	16,206	2,349	5,883	24,438
1924	14,587	2,257	5,044	21,888
1925	16,559	2,330	6,734	25,623
1926	19,013	2,341	7,965	29,319
1927	14,442	2,491	7,210	24,143
1928	12,526	2,727	7,078	22,331
1929	15,572	2,870	7,914	26,356
1930	11,640	2,866	6,734	21,240
1931	6,788	1,985	3,659	12,432
1932	10,444	1,027	3,569	15,040
1933	8,068	932	3,312	12,312
1934	12,520	1,368	4,309	18,197
1935	15,108	1,401	4,911	21,420
1936	18,523	2,070	5,297	25,890
1937	23,839	2,676	5,560	33,075
1938	19,286	2,066	6,141	27,493
1939	19,045	2,198	6,474	27,717

Early pipe lines. The first pipe line was proposed in 1860, and in 1862 Hutchison laid 3 miles of line. The first screwed pipe line which operated continuously was the Van Syckel line, 4 miles long, from Pithole to Miller's Farm, near Titusville, Pennsylvania. The pipe-line network spread rapidly, and by 1874 pipe lines had reached Pittsburgh. This was followed shortly by lines built to the Atlantic seaboard, and by 1906 the Mid-Continent fields were connected with the Gulf and also with the Atlantic seaboard.

At the same time that means of transportation were being developed on land, marine transportation was developing equally rapidly, and in 1875 the first steel tanker for carrying oil was built.

Fluctuations in prices of oils. The development of the early oil fields throughout the United States exhibited the same characteristics in all sections: rapid development, a high peak of production, and a rapid decline. Most wells yielded over 50 per cent of the oil in the first year of their existence. New pools were brought in with startling rapidity,

[4] Source: American Petroleum Institute, *Facts and Figures*, seventh edition (New York, 1940).

developed to a peak, and in a few years abandoned. Oil prices fluctuated with the discovery of each new pool and with the change in volume of supply. In the years between 1860 and 1868, the price of oil fluctuated more than 100 per cent annually, running from as low as 10 cents a barrel in 1862 to as high as $14.00 a barrel in 1864.

Early leaders in the industry. These violent fluctuations in the price of oil brought to leadership a number of brilliant men interested in the possibilities of the oil industry and determined to profit by it to the utmost. Among the most capable was John D. Rockefeller, a Cleveland produce merchant, who in turn interested such men as Henry Flagler, Samuel Adams, Stephen V. Harkness, and later Charles Pratt, H. H. Rodgers, and John D. Archibald. This group of men was primarily interested in refining and in a stable oil supply for their refining plants. They organized the Standard Oil Trust in 1870 in the State of Ohio, combined a number of refining properties, bought additional refineries, and went heavily into the pipe-line business, at the same time endeavoring to control transportation of oil on the railroads.

The discovery of oil in Texas was due to the activities of Captain A. F. Lucas, and just as the Pennsylvania fields proved the birthplace of the Standard Oil group, so the Texas fields were responsible for the development of another series of important oil corporations, including The Texas Company and the Gulf Oil Corporation; while the Oklahoma discoveries led to the founding of the Sinclair, Prairie, Phillips, Marland (now Continental) Companies, and many others.

In California, the discovery of oil led to the development of many large organizations, such as the Associated Oil Company, General Petroleum Company, and the Union Oil Company. Each new group of fields led to the forming of new corporations, since capable men could foresee the profits to be derived from the oil fields in the area in which they were peculiarly experienced.

Products of early refiners. The progress of the refining branch of the industry was slow. In the beginning, the matter of distillation was simple, and the first oil produced lent itself readily to the methods of treatment already discovered. The early refiners developed many special products, such as vaseline, special lubricants, and greases. The first great problem they encountered was the treatment of sulphur crudes originating from Ohio, which yielded corrosive oils. This problem was solved by the chemists of the Standard Oil Company and by Herman Frash, who later became inventor of the Frash process for producing sulphur. It should be noted, however, that the primary products in which the oil companies dealt in the early days of their development were kerosene and lubricating oil. Some fuel oil was made but not much. The voracious appetite of world commerce for kerosene and for lubricants as a concomitant of the increasing use of machinery consumed the available supply of crude oil.

Influence of the automobile on the petroleum industry. In 1890, however, the first automobiles appeared on the stage, although it was not until as late as 1895 that as many as 4 automobiles were registered in the

United States. Nor did the number reach 10,000 until 1901 and 1,000,000 until 1913.

The entrance of the automobile on the scene and the tremendous demand for a previous waste product, gasoline (some of which had already been sold for cleaning purposes and for certain restricted forms of lighting, the surplus being usually burned at the refineries, since it was dangerous in burning oils) completely changed the refining branch of the industry. Instead of kerosene, the despised by-product gasoline became most important, and the demand for it seemed insatiable. The situation as far as supply was concerned was further complicated by the fact that the oil pools discovered in the Mid-Continent and on the Gulf Coast, which by 1906 had become the important sources of crude oil, did not yield as large a percentage of gasoline as the lighter Pennsylvanian oils. The refiner then faced the problem of increasing the ratio of gasoline production to crude oil refined or of accumulating enormous stocks of other products which he could not sell The problem was attacked with all the energy that the industry could bring to bear upon it, and a solution was found in the development of the cracking process (the conversion of heavier oils into lighter ones by distillation under pressure), which enabled the industry to satisfy the increasing demand for gasoline without unduly increasing the production of by-products from crude oil other than fuel oil, which has been rapidly invading the markets previously held by coal.

TABLE V

CONSERVATION OF CRUDE OIL IN THE UNITED STATES BY THE USE OF IMPROVED METHODS FOR THE MANUFACTURE OF GASOLINE[5]
(in Barrels)

Year	*Crude Oil Required to Replace*		*Total Crude Oil Replaced*	*Actual Crude Oil Run to Stills*	*Crude Oil Required Without Improved Methods*
	Natural gasoline and benzol	*Cracked gasoline*			
1928	191,686,000	510,695,000	702,381,000	913,295,000	1,615,676,000
1929	226,819,000	579,680,000	806,499,000	987,708,000	1,794,207,000
1930	228,406,000	678,955,000	907,361,000	927,447,000	1,834,808,000
1931	184,826,000	717,603,000	902,429,000	894,608,000	1,797,037,000
1932	156,592,000	717,256,000	873,848,000	819,997,000	1,693,845,000
1933	154,877,000	795,220,000	950,097,000	861,254,000	1,811,351,000
1934	166,091,000	791,879,000	957,970,000	895,636,000	1,853,606,000
1935	181,478,000	914,071,000	1,095,549,000	965,790,000	2,061,339,000
1936	209,110,000	1,106,934,000	1,316,044,000	1,068,570,000	2,384,614,000
1937	244,411,000	1,261,098,000	1,505,509,000	1,183,440,000	2,688,949,000
1938	251,954,000	1,283,094,000	1,535,048,000	1,165,015,000	2,700,063,000
1939	248,725,000	1,402,653,000	1,651,378,000	1,237,840,000	2,889,218,000

[5] Source: Computed from United States Bureau of Mines data.

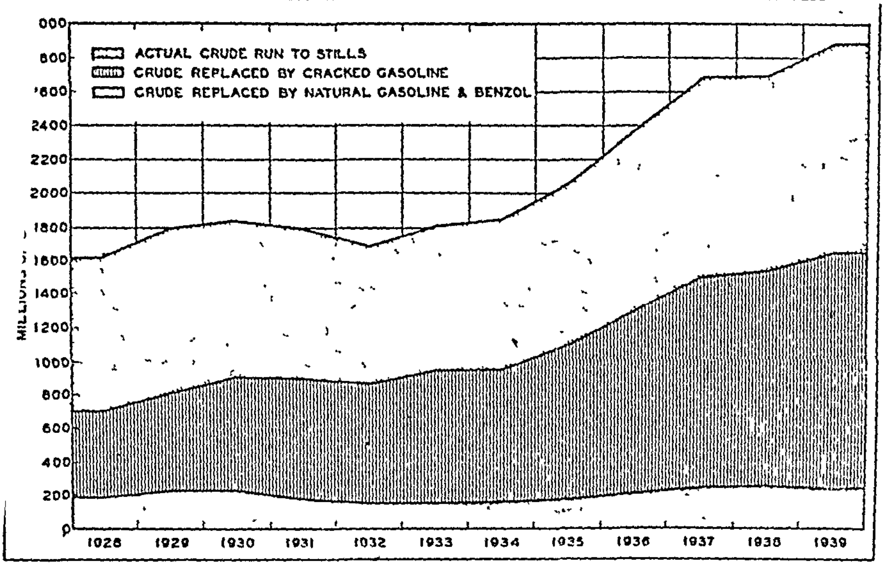


Fig. 2. Conservation of crude oil in the United States by the use of improved methods for the manufacture of gasoline.

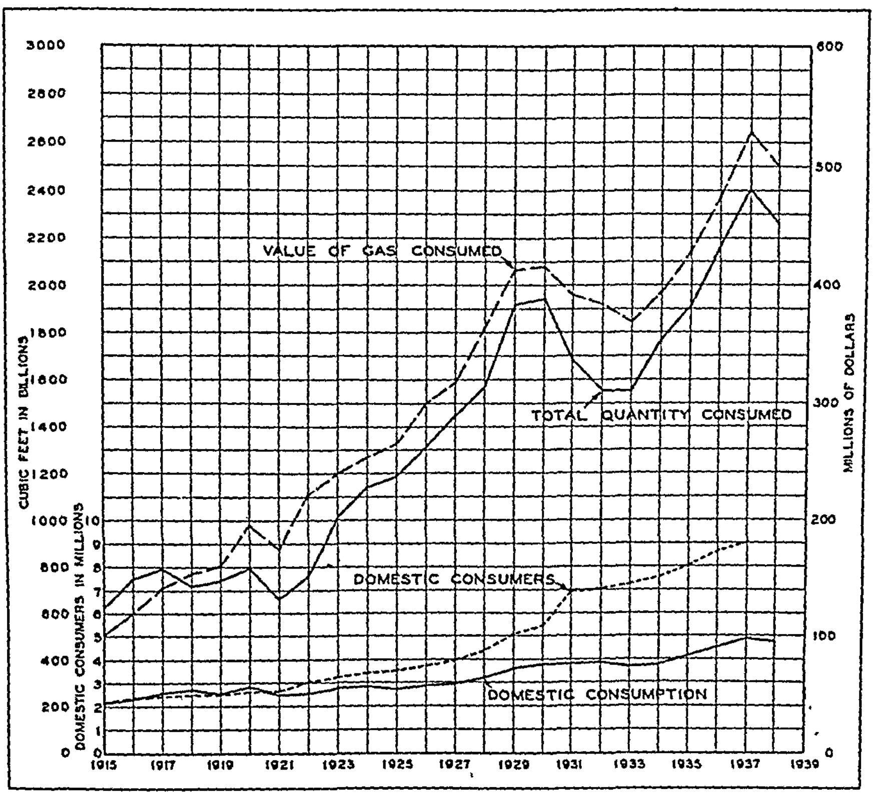


Fig 3 Growth of natural gas consumption in the United States from 1915 to 1939.

Importance of the cracking process. Figure 2 and Table V show the amount of crude oil which would have been necessary had the cracking process and natural gasoline not been available to supply the gasoline demand. It will be seen from these illustrations that approximately one barrel in every two of gasoline made in the United States is made by processes not in general use in 1910. The fact not shown in the chart is that the cracking process has led to the production of special gasolines necessary in modern aviation and for automotive engines.

TABLE VI

GROWTH OF NATURAL GAS CONSUMPTION IN THE UNITED STATES[8]

Year	*Natural Gas Consumption in Billions of Cubic Feet*		*Number of Domestic and Commercial Consumers in Thousands*	*Value of Gas Consumed in Millions of Dollars*
	Total Consumption	*Domestic and Commercial Consumption*		
1915	629	217	2,195	$101
1916	753	235	2,362	120
1917	795	258	2,431	142
1918	721	271	2,509	154
1919	746	256	2,501	161
1920	798	286	2,615	196
1921	662	248	2,631	175
1922	763	255	3,015	222
1923	1,007	277	3,234	240
1924	1,141	285	3,443	254
1925	1,188	272	3,508	265
1926	1,313	289	3,731	300
1927	1,445	296	3,984	318
1928	1,568	321	4,344	364
1929	1,917	360	5,098	413
1930	1,942	377	5,448	416
1931	1,684	381	6,961	392
1932	1,554	386	7,037	384
1933	1,553	369	7,232	368
1934	1,765	379	7,566	394
1935	1,910	414	8,004	428
1936	2,161	455	8,674	475
1937	2,403	489	9,028	528
1938	2,261	476	([a])	500
1939[a]	.....	...	....	..

[a] Not available.

Discovery of natural gas. Coincident with the discovery of oil, natural gas began to be produced either as a direct by-product of the oil production or as a result of the discovery of gas in wells drilled for oil. Its first use for domestic consumption on a small scale was in Fredonia, New York, in 1832. In 1872, gas was piped into Rochester, New York, and Titusville, Pennsylvania. The growth of the industry is shown in Figure 3.

[8] *Ibid.*

Natural gasoline (casinghead gasoline), which is the gasoline contained in natural gas, was first extracted from natural gas in 1904. It was not until 1911, however, that 1 per cent of the natural gas produced was treated to extract the gasoline. By 1928, 94 per cent of the gas produced and used was so treated.

Important Uses of Petroleum

Lubricants. It is probable that petroleum is used in more industries than any other commodity. Its first and most important use is that of lubrication. Practically all the wheels of the world are lubricated by oils with a petroleum base, and it is doubtful whether any substitute manufactured from any other known raw material could be produced in sufficient volume to supply the demand.

Source of power. Its next most important use is as a source of power in the gasoline engine, in airplanes and automobiles, and as fuel in the Diesel engines. It forms the most concentrated and readily transportable form of commercial energy known to man. One barrel of 20 degrees of A.P.I. gravity oil, which weighs 326 pounds, is equivalent in energy value to 517 pounds of coal of average grade. This difference is accentuated in the lighter grades of oil and gasolines; and, were it not for this fact, the present aviation industry would hardly be possible.

Fuel. Fuel oil competes with coal and has replaced it in certain markets: on land, in such places as California and certain parts of the Southern states, where coal suffers heavy transportation charges; at sea, as a marine fuel because of its high energy yield per unit of weight and the fact that it increases the cruising radius of ships, makes available additional space for cargo, and reduces the labor in the fire room. The lighter forms of fuel oil are displacing coal as a domestic fuel because of their easy handling and cleanliness.

Natural gas a form of domestic fuel. Natural gas, produced either with oil or as a result of exploration for oil, is now being piped over the United States to supply a cheap, readily available form of domestic fuel, and in places like California is now displacing fuel oil.

Carbon black, ethers, solvents, waxes, and so forth. Besides these major uses of petroleum products, carbon black is manufactured from gas and is used in making tires, inks, and similar products. From gasoline extracted from natural gas come liquefied gases, such as petroleum ethers used in hospitals, and numerous solvents, such as special alcohols. Certain petroleum oils are used in the making of soaps and as substitutes for linseed oil, while various commercial solvents prepared from gasoline are used for cleaning and in thinning paints and varnishes. Special oils have been developed for use in railroad signals and for the absorption of gasoline from natural gas. The heavy distillates yield paraffin and medicinal oils, ointments, and special oils for use in the flotation process. Waxes are used in the manufacture of chewing gum and candles, while still heavier oils are used for laying dust on roads, for asphalt shingles, roofing, asphalt pavements, and similar purposes. It is indeed difficult for us to imagine our present-day civilization without

oil. Stopping its production for even a short time would involve stopping the major part of our transportation facilities, such as automobiles, airplanes, and railroads. Its absence on the sea would reduce the carrying capacity of the world's mercantile marine by forcing a return to coal and, if lubricants were not available, possibly to sails.

Petroleum one of the largest industries. The production, marketing, and refining of petroleum represent one of the largest industries in the United States today. Petroleum products are sold through approximately 250,000 different retail outlets and contribute approximately 57,000,000 tons of freight per annum to the railroads. This does not include the large amount of material shipped by the oil companies to fields and plants for construction and operation purposes. The petroleum industry pays 12 per cent of the Panama Canal tolls, and 35 per cent of the world's shipping depends upon oil for motive power.

The Petroleum Industry Today

Production. Petroleum as such is produced from sedimentary rocks only, and where these do not occur, it will not be found in commercial quantities. The petroleum supply of the world is therefore limited to countries in which such rocks are found. Present distribution of petroleum production is shown in Table III. This distribution is governed by: (1) the natural distribution of petroleum resources among the various countries; (2) the laws of the various countries which govern its production; (3) the energy with which a search for it has been undertaken; (4) the distance from the productive areas to the consuming centers.

World sources. Two countries stand out preëminently in the production of petroleum and in future resources: the United States and Russia. Other countries that have important resources are: in North America, Mexico; in South America, Venezuela, Colombia, Peru, Argentine, Bolivia; in the West Indies, Trinidad; in Europe, Rumania, Poland, Russia, and Albania; in Asia, Asiatic Russia, including Russian Turkestan and Sakhalin, Iraq (Mesopotamia), Persia, Burma, Arabia, the Netherlands East Indies, and Bahrein. At present it does not seem probable that countries other than those listed above will produce petroleum in large enough quantities to export it beyond their own borders. The following countries have some petroleum resources, but these seem to be sufficient only to supply part of their local needs: in North America, Canada; in South America, Brazil; in the West Indies, Cuba and Barbados; in Europe, France, Italy, Germany, Hungary, and to a very small extent Spain and Czechoslovakia; in Asia, India, except Burma, and Japan; in Africa, Egypt, possibly the French colonies of Algeria, Morocco, and Madagascar, and Portuguese East and West Africa. On the whole, the possibilities of Africa producing any large quantities of petroleum seem to be very slight The same may be said of Australia, though there are possibilities in New Zealand and in the interior of Australia.

The interior of Asia, including the high plateau of Mongolia, a large part of China, and the great mountain ranges of Tibet, is almost devoid of petroleum possibilities. We know too little about the Antarctic continent to make a guess at the possibilities there; at present they seem to be of no consequence.

From the above it will be seen that the petroleum resources are distributed among relatively few countries and that these countries will continue to be important producers, while the rest will continue to be importers and buyers of petroleum produced by others.

Petroleum fields in the United States. The fields in the United States are usually grouped in five sections: the Eastern fields, Mid-Continent fields, Gulf Coast fields, Rocky Mountain fields, and California fields. Crude oil produced in these different oil fields is of various types and qualities. However, each group has certain general characteristics.

The Eastern fields. These may be divided into the Appalachian and Middle Western fields. The Appalachian part of the Eastern fields, including the States of New York, Pennsylvania, West Virginia, Kentucky, and Tennessee, produces light crude oils, usually of paraffin base, with desirable lubricating oil content and high yields of gasoline and kerosene. These oils have until recently been refined by the straight-run process instead of being cracked. The gasolines from these oils have low antiknock ratings. The producing sands are all of Paleozoic age.

The Middle Western fields, which include the States of Ohio, Indiana, Michigan, and Illinois, in some cases produce heavier oils of mixed base containing sulphur compounds which require special treatment; in other cases, as in the new fields in Illinois and Michigan, they produce sweet oils. As a rule, these oils are used for the manufacture of gasoline, kerosene, and fuel oil. The producing sands are all of the Paleozoic age.

The Mid-Continent field. In the Mid-Continent, which at present is the largest single producing group in the United States, a number of different types of oils are produced, varying from very light, paraffin-base oils to very heavy, asphaltic-base oils. The largest reserves in the United States occur in this area. The Mid-Continent fields include southeastern New Mexico, all of Texas except a strip along the coast, northern Louisiana, and the States of Arkansas, Oklahoma, and Kansas. Oils are produced in this area from rocks ranging from Cretaceous to Lower Ordovician in age and are the source of large quantities of gasoline, kerosene, and lubricating oils.

The Gulf Coast fields. These fields include the coastal strip extending from the mouth of the Mississippi River down to the Mexican border. The oil produced from these fields is of many grades, but when cracked yields desirable grades of gasoline, with high antiknock value, and fuel oil. It is also the base of good lubricating oils. Production is obtained from beds of Tertiary age and in particular from those peculiar structures known as "salt domes," where a salt plug has been forced up through and has tilted sedimentary beds from which the oil production is secured.

The Rocky Mountain fields. These fields include two distinct types of oils. Certain Permian formations yield "black oils," which are high in sulphur content and difficult to refine. Most of the production from the Rocky Mountain district is, however, from rock of Eocene, Cretaceous, and Jurassic ages; it is of mixed base, rather light gravity, and is used for the production of gasoline and lubricating oils and a small amount of fuel oil. These oils are more or less sulphur-free. The Rocky Mountain production comes from the following states: northwestern New Mexico, Colorado, Wyoming, and Montana.

The California fields. Practically all the oil in this region is produced from Tertiary beds and ranges from the very light, gasoline-like oils produced at Kettleman Hills to the very heavy, asphaltic-base oils produced at Kern River. While confined to a relatively small area, the California fields are marked by a high per-acre yield. They are usually divided into three sections: the San Joaquin Valley, Ventura County, and the Los Angeles Basin.

TABLE VII

PETROLEUM PRODUCTION IN THE UNITED STATES FOR 1938[7]

State	*Production in Thousands of Barrels*	*Value in Thousands of Dollars*
Arkansas	18,180	$ 16,900
California	249,749	257,250
Colorado	1,412	1,540
Illinois	24,075	30,100
Indiana	995	1,260
Kansas	60,064	72,100
Kentucky	5,821	7,570
Louisiana	95,208	110,100
Michigan	18,745	19,300
Montana	4,946	5,190
New Mexico	35,759	33,250
New York	5,045	9,550
Ohio	3,298	3,860
Oklahoma	174,994	209,500
Pennsylvania	17,426	32,760
Texas	475,850	539,150
West Virginia	3,684	5,600
Wyoming	19,022	12,000
Other states[a]	82	80
Total	1,214,355	$1,367,060

[a] Missouri, Tennessee, and Utah.

Reserves. The crude petroleum reserves of the United States are estimated annually by the American Petroleum Institute and the reserves as to districts are shown in the following table.

[7] *Ibid.*

TABLE VIII

ESTIMATED PROVEN PETROLEUM RESERVES IN THE UNITED STATES
(in Barrels of 42 Gallons)

State	*Production*[8] *During 1939*	*Per Cent of Total*	*API Committee Report of Proved Reserves as of January 1, 1940*	*Per Cent of Total*	*Reserve Years Supply*
Arkansas	21,143,000	1.67%	320,148,000	1.73%	15.14
California	224,354,000	17.75	3,532,342,000	19.11	15.74
Colorado	1,391,000	.11	20,162,000	.11	14.49
Illinois	94,302,000	7.46	381,636,000	2.06	4.05
Indiana	1,443,000	.12	14,164,000	.07	9.82
Kansas	60,723,000	4.80	725,467,000	3.93	11.95
Kentucky	5,581,000	.44	44,086,000	.24	7.90
Louisiana	93,869,000	7.43	1,173,225,000	6.35	12.50
Michigan	22,799,000	1.80	51,078,000	.28	2.24
Montana	5,961,000	.47	93,460,000	.51	15.68
New Mexico	37,323,000	2.95	687,168,000	3.72	18.41
New York	5,098,000	.40	35,392,000	.19	6.94
Ohio	3,156,000	.25	31,692,000	.17	10.04
Oklahoma	160,072,000	12.66	1,063,152,000	5.75	6.64
Pennsylvania	17,337,000	1.37	183,123,000	.99	10.56
Texas	484,527,000	38.33	9,768,371,000	52.85	20.16
West Virginia	3,580,000	.28	45,888,000	.25	12.82
Wyoming	21,417,000	1.69	305,616,000	1.65	14.27
Other states[a]	180,000	.02	6,842,000	.04	38.00
Total	1,264,256,000	100.00%	18,483,012,000	100.00%	14.62

[a] Mississippi, Nebraska, Tennessee, Missouri, and Utah.

Geographical Location of Refining Centers

The refining industry has grown up around the various sources mentioned, and we find that the location of refineries is controlled by two factors: (1) a supply of "crude" which can be moved to the refinery at low cost; and (2) the location and nature of the consuming market.

From a glance at the accompanying maps of the United States and the world, it will be noted that the great refining centers in the United States are: (1) A group of refineries on the Atlantic seaboard around the ports of New York and Philadelphia, which supply the great consuming markets of the Eastern United States. Crude is brought to these refineries by pipe lines extending from the interior of the United States, across the Alleghenies to New York. Tankers also bring supplies from foreign Caribbean sources, such as Venezuela, Colombia, and Mexico, or from marine terminals of pipe lines from the Mid-Continent and Gulf Coastal fields at the Gulf Coast. (2) A group of refineries about the mouth of the Mississippi River between New Orleans and Baton Rouge.

[8] *Ibid.*

These refineries again depend upon water transportation for crude oil or on pipe lines from the interior. They distribute by barge and tank car. (3) A group of refineries around the towns of Beaumont, Port Arthur, and Houston, at the terminus of pipe lines from the Mid-Continent and contiguous to the Gulf Coast fields. They depend largely on water transport for their product.

Two other important centers are Chicago and St. Louis, where there are large markets and where oils are brought to the refineries from the Mid-Continent and Middle Western fields by pipe lines. An old refining center exists at Pittsburgh, where a number of plants grew up in the early days to refine oil produced from the fields close at hand. Cleveland was also another important refining center for the Pennslyvanian oils, as it lay on Lake Erie close to water transportation and a network of railroads.

In the Mid-Continent, the Tulsa and Dallas districts are both important refining centers, owing to the proximity of supplies of crude oil and the existence of important railroad centers. In the Rocky Mountains, Casper, near the Salt Creek field, is important. Refineries of local importance grew up with the production of oil from fields in northern Wyoming, Montana, and Colorado.

In California, oil for refineries is mainly moved to tide water, and we find the great refining centers in San Francisco and Los Angeles in association with these ports, oil being brought from the interior to the refineries by pipe lines.

Transportation a factor in location of refining centers. It will be seen from the above account that, as a rule, petroleum is moved in its crude state from the producing centers, preferably by cheap water transportation, or, when this is not available, by pipe lines to consuming centers, where it is refined, the location of the refineries depending primarily upon transportation facilities. Refineries must sell in each local market the products available by the distillation of the crude oil they use. This fact has had its effect on the refining practice in various areas, making cracking more important on the Gulf Coast, where the chief demand is for gasoline, than in California, where there has been a relatively large demand for fuel oil because of the high cost of coal. An important departure from this generalization has been the recent construction of a number of gasoline pipe lines for the transportation of gasoline from refining centers. These new pipe lines will enable the refineries manufacturing gasoline to transport to certain districts the products that market will absorb. (See Figure 4.)

Important refining centers abroad. What has been said here of the refining industry in the United States is true also in other countries. The Rumanian center, Ploesti, is close to the Rumanian fields and is connected by pipe lines with the two most important transportation points, Guirgevo on the Danube and Constantza on the Black Sea, so that Rumanian products may be distributed via the Danube into the interior of Europe and via the Black Sea to the Mediterranean markets. The big refining center at Baku is dependent upon the Baku fields, and dis-

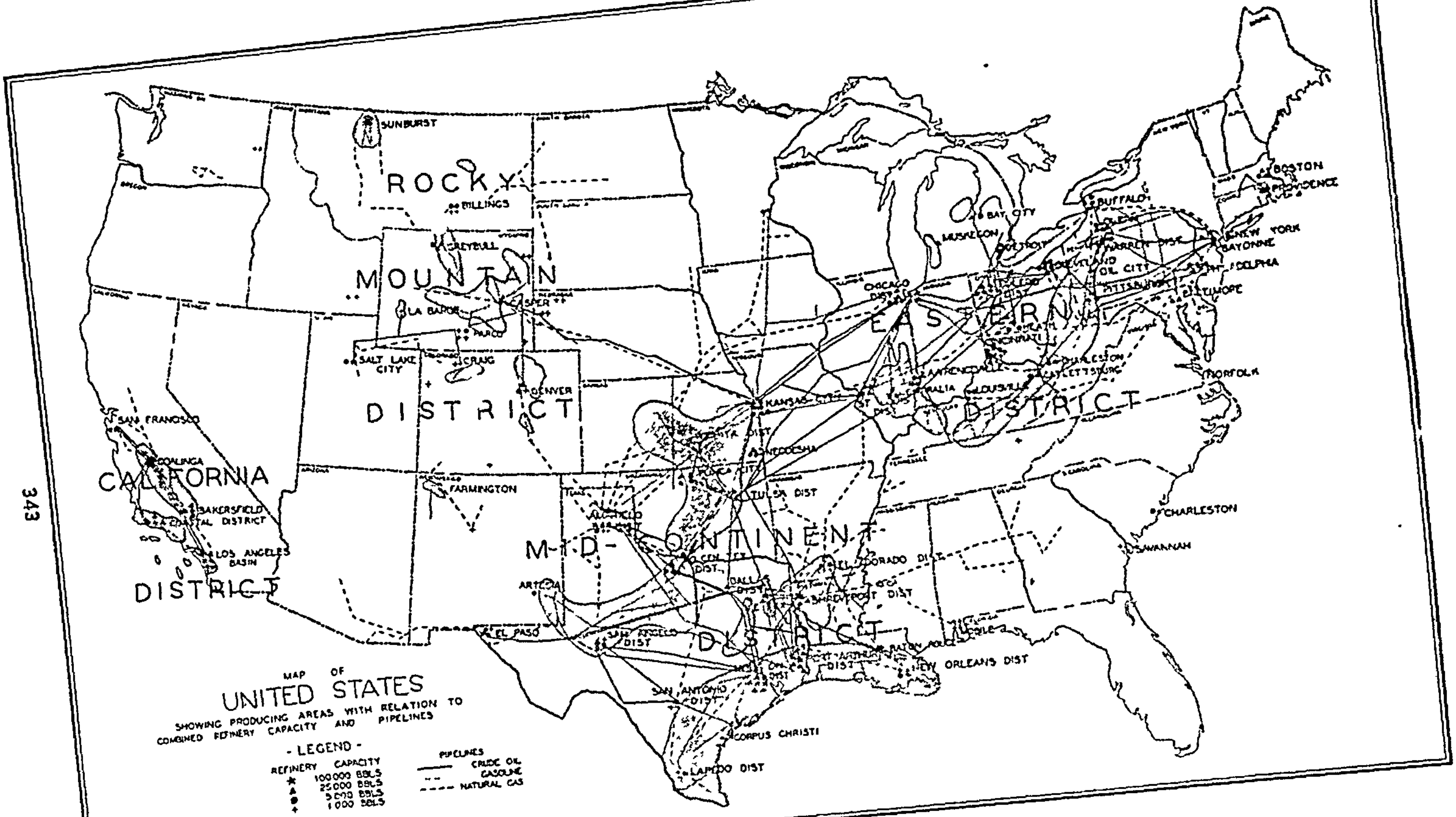

MAP OF
UNITED STATES
SHOWING PRODUCING AREAS WITH RELATION TO
COMBINED REFINERY CAPACITY AND PIPELINES
- LEGEND -
REFINERY CAPACITY
100000 BBLS
25000 BBLS
5000 BBLS
1000 BBLS
PIPELINES
CRUDE OIL
GASOLINE
NATURAL GAS
PRODUCING AREAS
ROCKY MOUNTAIN DISTRICT
CALIFORNIA DISTRICT
MID-CONTINENT DISTRICT
EASTERN DISTRICT
SUNBURST
BILLINGS
GREYBULL
CASPER
LA BARGE
PARCO
SALT LAKE CITY
CRAIG
DENVER
FARMINGTON
ARTESIA
EL PASO
SAN FRANCISCO
COALINGA
BAKERSFIELD
COASTAL DISTRICT
LOS ANGELES BASIN
KANSAS CITY
NEODESHA
TULSA DIST
SAN ANGELO DIST
SAN ANTONIO DIST
CORPUS CHRISTI
LAREDO DIST
EL DORADO DIST
SHREVEPORT DIST
PORT ARTHUR DIST
BATON ROUGE
NEW ORLEANS DIST
CHICAGO DIST
MUSKEGON
BAY CITY
DETROIT
TOLEDO
CLEVELAND
OIL CITY
WARREN DIST
PITTSBURGH
CINCINNATI
LOUISVILLE
CHARLESTON
CATLETTSBURG
BUFFALO
OLEAN
BOSTON
PROVIDENCE
NEW YORK
BAYONNE
PHILADELPHIA
BALTIMORE
NORFOLK
CHARLESTON
SAVANNAH

Fig. 4.

tribution is secured by pipe lines to the Black Sea and by marine transportation on the Caspian Sea up the Volga River to the center of Russia. The Egyptian refineries depend on the Egyptian fields, and their location at the end of the Suez Canal is advantageous for both fuel oil markets and transportation. The refining centers in England manufacture products from oil brought by water from Trinidad, Venezuela, and Persia, which they distribute in northern Europe. The great refining centers at Curaçao and Aruba are closely associated with the Venezuelan oil fields, and are located very advantageously for distributing oil to countries surrounding the Atlantic and diverting their oil from market to market as may seem desirable (See Figure 4a.)

A recent tendency in many foreign countries has been legislation setting up a differential in favor of crude oil importations rather than of the finished product. The effect of this differential custom duty has been to cause the establishment within these countries of refining centers where they would otherwise not be placed, the differential duty serving as a sort of bounty for the construction of a plant to refine crude oil in the country in which it is consumed.

Development of Oil Fields

Scientific determination of the presence of oil. Large companies maintain staffs of geologists and geophysicists who are continually searching for new oil pools. Formerly, a large proportion of the production of the world was obtained from wells not more than a year old, and exploratory work had to be continued if the needs of the world were to be supplied. Pratt,[9] in an article, has stated that it is necessary to drill 20,000 new wells and prove up 50,000 acres of new oil fields per year to maintain our supply.

In the main, this generalization still holds; however, the discovery in recent years of huge deposits, such as the East Texas field, has had the temporary result of bringing reserves in sight that exceed the immediate need. There is at present more than 18 years' supply developed for the United States.

In general, oil is found in anticlines or upfolds in the sedimentary rocks. Consequently, the search for new oil pools is carried on by mapping the surface formations, by studying and comparing cores and samples from wells, both as to their mineral content and the fossils they contain; and by the use of various methods, usually called "geophysical," for investigating the physical properties of the formations underlying the surface of the earth. These methods may involve the use of explosives for the making of small earthquakes that are recorded by seismographs, and the rate of transmission of waves through the underlying formations is interpreted to determine the attitude and type of formations underlying a particular area; or the use of the torsion balance, which determines the variation of the force of gravity from place to place and

[9] Pratt, Wallace E., *Oil and Gas Journal* (July 16, 1931), p. 19.

enables geologists to locate heavier or lighter formations when these are folded up toward the surface of the earth. The gravity meter is now used for the same purpose and is replacing the torsion balance. The study of samples taken from wells frequently involves microscopic examination of cores and correlations of the fossils and minerals found in the samples, so that the different formations can be related from well to well. Recently, electric cores, or a study of the resistivity of the formations penetrated, has also been of substantial aid to the geologist in making correlations.

Procuring oil land leases. By the use of the great mass of data so accumulated, geologists are able to eliminate many areas as nonprospective and to reduce materially the hazards of prospecting for oil. Nevertheless, 1 well in every 4 drilled is dry, and of wildcat wells only 1 well in 25 brings in a new field. It has become increasingly difficult to discover oil as development continues and the easily discoverable prospects are drilled. After the geologist has recommended an area for prospecting, the land is leased and wells are drilled to test the lands so acquired. In areas where the geology is obscure, it has been customary with the larger *companies to "checkerboard," or buy spreads. This term means that, in* prospective territory where the geologist cannot localize the possibilities for the discovery of oil, the larger corporations have bought leases so scattered as to permit them to participate in the results of any discoveries made in the area. This process differs from the direct selection of acreage in the same way that a rifle shot differs from a shotgun shot; in the one the bullet is sent directly to the mark, and in the other sufficient small bullets are fired so that the mark is hit by one of them.

A lease usually entitles the landowner to one eighth of the oil or gas produced and usually runs for from 5 to 10 years, unless oil or gas is discovered, in which case it runs as long as these substances are produced. Until a well is drilled, the landowner receives a yearly rental; thereafter he receives only his royalty.

With the drilling of the well begins the series of complicated technical operations which result in the production of oil.

Methods of drilling wells. Drilling technique has improved markedly in the last 20 years. Prior to 1918, almost all wells, with the exception of those on the Gulf Coast, were drilled by the cable tool method, while in recent years the rotary method has taken its place on almost all the territory, except in the Appalachian region.[10]

The rotary system. This method now holds all records for depth of drilling. The improvement in drilling which has led to these records for great depths has been brought about by the use of heavier and stronger materials, such as casing, drill pipe, and larger derricks and engines. As wells are drilled deeper, they of course become more costly, and wells drilled to a depth of over 10,000 feet frequently cost $500,000 or more.

Wells have now been drilled to depths of 15,000 feet, and it appears

[10] Descriptions of the rotary and cable-tool drilling methods may be found in Uren's *Petroleum Engineering* (New York: McGraw-Hill Book Company, Inc., 1924).

that they may be satisfactorily carried to even greater depths, provided the rewards are great enough to justify the effort. The average cost of wells drilled in the United States is about $25,000. The growing cost of drilling of the very deep prospects now undergoing development in Texas and California has brought about the very serious consideration of the amount of oil which can be produced from each well. Whenever a pool is divided into small lots and each owner has drilled wells to capture his share of the oil, the proportion of recoverable oil per well is small, which of course increases the total cost of producing the oil from the field. This problem becomes more important as wells get deeper, for a well of 15,000 feet in depth costs some hundreds of thousands of dollars.

During the period of development of the industry up to 1930, the demand for oil always ran fairly close to the supply and temporary gluts were followed by periods of scarcity. Under these circumstances, when fields were discovered the wells drilled were produced as rapidly as possible, both to supply the demand and because of competition for the oil between the owners of the various parcels on any geological structure. The energy contained within the oil pool itself (the original pressure of the oil and gas in the pool) was by this very process used inefficiently to bring the oil to the surface. Much of this inefficiency has been credited in the United States to the legal system under which the oil was produced, the much discussed "Law of Capture," but it was due also to a lack of understanding of the physics of the occurrence of oil and gas on the part of the producers themselves. Engineers, however, by continuous experimentation found that, by regulating the flow of wells so that each barrel was lifted to the surface by the agency of the smallest amount of reservoir energy (the original pressure in the pool), the cost of producing oil could be substantially reduced and at the same time a greater amount of oil could be ultimately recovered from the sands. This is a slow process, but it is now believed by many engineers that, if the oil pool is produced slowly enough, almost the entire quantity of oil in the sand can be produced by the pool's store of natural energy and pumping will not have to be resorted to on a large scale. However, this slower rate of recovery, established as the best engineering practice, must be applied to each oil and gas pool in toto, for if one owner or group of owners pulls oil more rapidly than another, the equilibrium in the oil sand will be upset and the oil will migrate to the wells which are being pulled upon the fastest, with the result that the oil is inequitably distributed among the several owners. As a result, in most producing areas the state has stepped in as arbiter between the various producers in new pools under the various proration statutes to see that reasonable justice is done between the individuals concerned. Oil produced in defiance of state regulations is known to the oil trade as "hot oil," and its production is really a special form of theft, as it may be said to be stolen from all the neighbors of the well so produced. This general change in production practice has had far-reaching effects in the producing operations. Formerly, the return from producing operations was rapid in the beginning of a field and the last few barrels of oil were won by slow and expensive methods.

In prorated fields, on the other hand, "bonanza" oil is not produced in the beginning, but this is compensated for by the more consistent return from the pool and lower average ultimate cost. Under this system large reserves have been built up in the United States which will be available in case national emergency demands more rapid production. In many old fields pumping wells produce oil for many years often at rates of less than a barrel per day, but the expense of producing such oil is always a race between the cost of production and the money return, so that a relatively small decrease in the price of oil will inevitably stop production on thousands of these wells; and once they are abandoned, the oil which would have been recovered from them in old fields may be irretrievably lost, for the expense of drilling new wells to produce such oil as remains would not be justified. Wells of this class producing less than 5 barrels per day are known as "stripper" wells. There are producing in the country at the present time 373,500 oil wells and 57,000 gas wells, and over 200,000 of the oil wells belong to the "stripper" class.

Methods of extracting oil. Oil may be produced by flowing under natural reservoir pressure, by gas or air lift, where gas or air is pumped into the well and lifts the oil to the surface, or by pumping. It is probable that the average cost of flowing oil is not more than 10 cents a barrel, while gas- or air-lift production costs 25 cents a barrel, and pumping production may cost over $1, depending upon the depth and other characteristics of the well. The above figures do not include the initial cost of drilling the well Wells quite usually produce some sand and mud together with the oil, and some salt water frequently accompanies it, particularly in the later stages of a well's life. Sand, of course, must be settled out of the oil, and the salt water is drained periodically from the tanks into which that oil is flowed These substances are usually grouped as "B. S.," or bottom settlings, in pipe-line reports and are measured with the oil in the lease tanks into which it is flowed. Gas produced with the oil is separated by the use of gas separators and is either used as fuel or passed through a gasoline plant for the purpose of extracting natural gasoline, after which dry gas is either sold or returned to the field to aid in the production of oil. The cubic feet of gas produced by a well with each barrel of oil is called the "oil-gas ratio," and this ratio is in some measure the gauge of the efficiency of well operation. The salt water, particularly in the last stages of the well, may become emulsified with the oil produced, and this emulsion has in some cases to be treated by heating or by the addition of a chemical, such as treatolite, or electrolized.

Important factors in costs of production. All these subsidiary operations add to the cost of producing the oil. It is to be noted, however, that, in addition to the actual expense of operating an oil well, two of the most important cost factors in oil production are: (1) the cost of acquiring a lease property from which to produce it, "the lease bonus"; and (2) the payment of royalties on production. In the United States, the usual royalty paid by the leaseholder to the owner of the land is one eighth. When it is considered that this one eighth is free and clear of all other charges, it will be seen that the landowner receives more than the oil company in net profit.

Transportation

Pipe lines. Once the oil is brought to the surface, it is usually transported to refineries by pipe line. The capacity of the line varies with the size of the pipe, the distance between pumping stations, the pressure at which the oil is pumped, and the viscosity of the oil. The oil in the field is pumped or flowed into gas separators and the gas is separated; the oil is then flowed or pumped into tanks, gauged as to volume and corrections made for temperature, B. S., and water, and finally run through the pipe line. As a rule, the oil is purchased in the field at the lease tanks by the refiner.

Tank cars. When big pools are discovered and the production increases more rapidly than pipe lines can be constructed to carry it, the surplus oil is often run to tank cars and transported by rail to the refining centers.

Use of storage tanks. In other cases in the past, oil companies erected storage facilities on the ground and ran the oil to large tanks, removing it later when the production of the field diminished. The investment in tankage contrasted with the cost of additional pipe-line facilities had to be carefully calculated under such conditions, for it was sometimes very difficult to judge the amount of oil that would be produced by a pool from its performance in the early stages of development, and in more than one case lines were laid and tanks erected by companies who later found that there was no oil to transport through them. The present tendency of the industry is to keep oil below ground—that is, to produce it as needed.

Work of the pipe-line company. The transporting company usually charges a fee for gathering the oil and another fee for transporting it to the refinery. Standard rates of deduction are made for losses, as from evaporation, in pipe-line transmission. These losses have been reduced to a minimum. Pipe lines usually operate on a dispatch system, the oil being dispatched through the line in the same way that trains are run on the single-track railway. The pump man in each pump station records the amount and type of oil passing through the station from time to time, and enables the company to identify any batch of oil transported. In some cases, in order to separate the various grades of oil, water slugs are pumped in between the various batches of oil, and the arrival of this water is a signal for the pump-station operator to turn the stream of oil into a separate tank.

Pipe-line systems. The network of pipe lines in the United States is shown in Figure 4. In 1940, there were 59,000 miles of crude-oil pipe lines, 81,000 miles of natural-gas pipe lines, and 10,000 miles of gasoline pipe lines. In addition, there are also 55,000 miles of gathering lines for crude oil and 102,000 miles of distributing lines for natural-gas systems. The investment in present facilities exceeds $2,000,000,000.

Co-extensive with the system of pipe lines for oil transportation has grown up a great system of gas lines through which is transported to consuming centers the gas produced as a by-product of the production of oil or discovered in the search for it. These pipe-line systems have re-

cently connected the Mid-Continent fields with Chicago and Detroit, and the San Joaquin Valley with the San Francisco and Los Angeles districts. The general tendency of this development is to interconnect gas systems from the various producing centers so that gas from any one district may be diverted to the point of greatest need. The use of gas transported by pipe line has increased rapidly, but the accompanying chart (Figure 3) shows the effect of the great depression on the gas industry. The great shrinkage in the consumption of natural gas shown in 1930 to 1933 was due, in the main, to shrinkage in industrial consumption.

Storage of Oil

In the past, oil from flush fields was frequently stored in order to cut down the investment in facilities for moving it from the field, but this tendency has decreased markedly in later years as it has been recognized that the best place to store oil is underground, and stocks of crude oil on the surface have been limited largely to those necessary working stocks for pipe-line and refining companies. The storage, under modern conditions, is usually done in vapor-tight steel tanks, which prevent the evaporation of the light constituents of the oil. These tanks are usually erected in groups. The standard sizes for the storage of crude oil have capacities of 55,000, 80,000, and 125,000 barrels. They are surrounded by embankments or fire walls, which would contain the oil should the tank burst or catch fire. The cost of such steel storage varies, but it is now estimated at 25 cents per barrel per annum, which allows for loss by evaporation, depreciation on the tank (except in the case of oils with high sulphur content, which are apt to be corrosive), land rental, interest, and insurance on oil worth 1 dollar per barrel. In the case of refined products, special forms of tanks have been developed for the lighter products, such as the hemispherical and oval tanks for natural gasoline, which are painted with aluminum paint to minimize evaporation. Stocks of gasoline usually rise in winter months. Of late, the industry has tended to increase these stocks beyond reasonable working needs. This has been brought about by the great increase in the demand for domestic fuel oil, a market which was originally developed to take care of products produced as a result of the intensive refining for gasoline. It is to be pointed out, however, that a balance has to be struck, with reference to the demand for a seasonal product of the type of gasoline, between the cost of maintaining excess stocks and that of maintaining the excess plant capacity which will have to be put in operation during the season of greatest demand.

The Refining Processes

The cracking process. As crude oil is a mixture of hydrocarbons, its refining, until the invention of cracking, consisted of its fractional distillation and the treatment of the various fractions to remove such impurities as sulphur. As long as the ratio of products produced by this

process was approximately the same as the market demand for the various products, the process was efficient. When, however, the demand for gasoline, owing to the use of the gasoline motor, was tremendously increased, without any corresponding increase in demand for the other products, the refiner was forced to develop means of converting the heavier fractions of crude oil into the lighter gasoline or to be faced with marketing his other products at ruinously low prices, which in turn would have necessitated his charging higher prices for gasoline to make up his other losses. This condition led to the development of the cracking process. Distillation is, of course, the simple physical separation of a liquid hydrocarbon into fractions of different boiling points; the cracking process, which involves distillation at high temperature and pressure, involves the actual chemical breaking down of the heavy hydrocarbons into lighter hydrocarbons and carbon. In the even newer hydrogenation process, the oil is cracked under pressure in the presence of hydrogen and additional hydrocarbons are formed from the surplus carbon. Recently catalytic cracking has come to the fore, where a catalyst is present in the cracking still to accelerate the chemical changes that produce lighter hydrocarbons from the heavier.

Originators of the cracking process. Cracking processes were developed simultaneously by several groups: the Burton process, by D. Burton of the Standard Oil Company of Indiana; the Holmes-Manley process, based on patents of F. H. Adams, by the Texas Company; the Dubbs process; the Cross process; and the Tube and Tank process. Patent litigation was begun between the various companies holding patents but was settled by agreement, as it became evident that its continuance would only result in a chaos of litigation. Active research has been continued by all the competing companies, and cracking processes are continually being improved.

Types of modern refineries. Modern refineries may be divided into three general types: the skimming plant, the complete distillation plant, and the cracking plant. In the first type, the gasoline and kerosene fractions of the crude oil are distilled or skimmed off, and the remaining heavy oil is marketed as fuel oil. In the second type, the crude oil is distilled down to coke or asphalt, and the various fractions distilled off after the gasoline and kerosene are refined to lubricants, greases, and other special products. In the cracking plant the fractions between the kerosene fraction and tar and coke are redistilled under high pressure and at high temperature, sometimes in the presence of a catalyst, to form additional gasoline. All varieties of combinations of the three forms exist. The complete distillation plants are usually large-scale operations, while the skimming plants are usually designed to supply local needs. After the oils are distilled over, they are treated to remove impurities and in many cases are redistilled. The treatment may consist of washing with sulphuric acid solution and then neutralizing the oil with caustic soda or of agitation with clay of the fuller's earth type and by filtration. These treatments remove from the oil resinous bodies and some unsaturated hydrocarbons which are objectionable on the score of

color, odor, or tendency to corrode machine parts. Sulphurous oils have demanded special treatment with cuprous oxide, as in the Frash process, or with liquid sulphur dioxide, as in the Edelneau process. From the heavier fractions of oil used for lubrication wax must be extracted. This is usually done by chilling the oil and filtering out the wax, which is then further treated to a sweating process to make the wax of commerce; or it may be done by solvent refining, in which case a solvent for the wax is added to the oil, they are both agitated together, and the wax is carried off by the solvent, which is then redistilled and used for repeated applications.

After these processes, special products are made by blending the various oils and greases, sometimes with each other and sometimes with soaps and animal fats, depending upon the special use to which they are to be put.

Blending gasolines. Gasoline is frequently blended to give it special qualities; for instance, the very light natural gasolines are frequently blended with heavier gasolines to give a quick starting product for winter use. The study of knocking as it affects the power of gasoline motors has also changed the specifications for gasoline. High-compression motors are the most efficient users of gasoline, but their tendency to knock with ordinary gasolines for a considerable time prevented their extensive use.

It has been found, however, that some gasolines from the cracking still would operate a motor with less knock than straight-run gasoline, and it has also been found that the addition of tetraethyl lead and similar products to gasoline will decrease the tendency to knock. A measure of antiknocking quality of gasoline is furnished by what is called the "octane number," which has become most important in connection with aviation. Aviation engines, with extremely high compression ratios, must deliver the maximum amount of power from the smallest weight per engine horsepower, and the antiknock gasolines used in these motors run up to an octane number of 100. Similarly, the average octane number of standard brands of motor fuel has risen from approximately 55 to 72 within the last few years, enabling the manufacturers of automobiles to increase the efficiency of their motors. Competition between brands forces a continued improvement in gasoline sold to the public, and all the larger oil companies maintain research organizations which continually and intensively study this problem.

Petroleum products. A consideration of a few figures on the main products produced by the industry will show the change in demand, which has been the most important phenomenon in refineries in recent years. (See Tables IX, X, and Figure 5).

Figure 5a shows the products manufactured from petroleum and gas at the present time. The companies with complete plants usually maintain research departments, which are continually at work improving processes of manufacture and the quality of the product sold to the public.

Besides the products listed in Figure 5a, the exploration for oil has resulted in the discovery of large supplies of such minerals as sulphur,

TABLE IX

CRUDE RUN TO STILLS AND REFINERY OUTPUT IN THE UNITED STATES[11]
(In Barrels; 000 Omitted)

Year	*Gasoline*	*Kerosene*	*Lubricants*	*All Other Products*	*Crude Run to Stills*
1928	341,722	59,353	34,658	477,562	913,295
1929	388,621	55,940	34,359	508,788	987,708
1930	389,071	49,208	34,201	454,967	927,447
1931	396,394	42,446	26,704	429,064	894,608
1932	366,291	43,836	22,433	387,437	819,997
1933	376,245	48,977	23,775	412,257	861,254
1934	388,770	53,855	26,373	426,638	895,636
1935	426,817	55,813	27,853	455,307	965,790
1936	470,994	56,082	30,927	510,567	1,068,570
1937	519,760	65,308	35,321	563,051	1,183,440
1938	516,051	64,580	30,826	553,558	1,165,015
1939	555,605	68,521	35,036	578,678	1,237,840

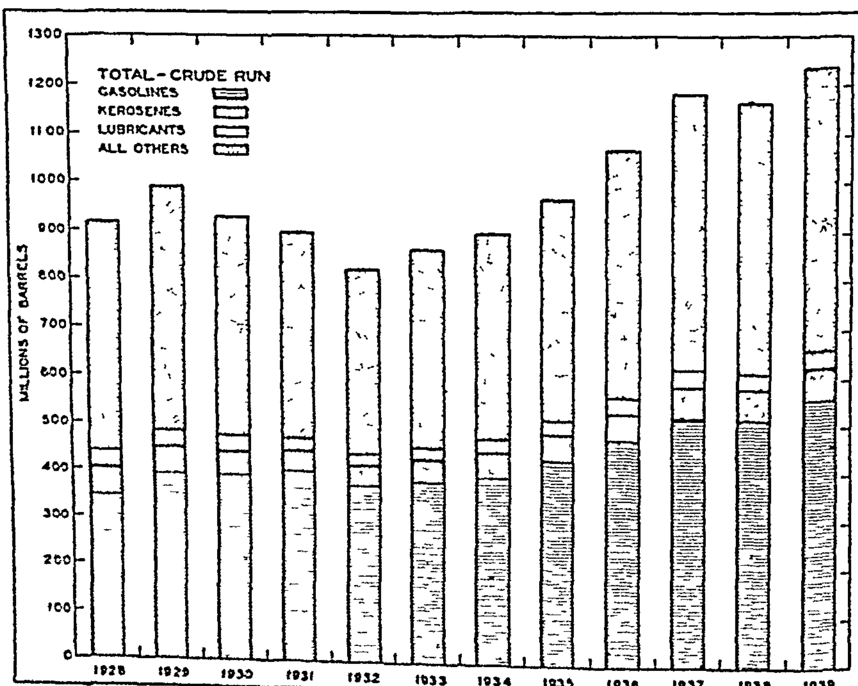


FIG. 5. Crude run to stills and refinery output in the United States from 1928 to 1939.

[11] Source: United States Bureau of Mines.

TABLE X

CHANGING PROPORTIONS OF PRODUCTS PRODUCED FROM CRUDE OIL BY UNITED STATES REFINERIES[12]

(In Thousands of Barrels)

Year	Crude Oil Refined	Straight-Run Gasoline	Per Cent of Crude-Oil Run	Natural Gasoline[a]	Cracked Gasoline	Per Cent of Crude-Oil Run	Kerosene	Per Cent of Crude-Oil Run	Gas and Fuel Oil	Per Cent of Crude-Oil Run	Lubricating Oil	Per Cent of Crude-Oil Run
1880	17,417	1,788	10.27%	—	—	—	13,098	75.20%	—	—	369	2.12%
1889	30,663	3,917	12.77	—	—	—	20,199	65.87	—	—	2,301	7.50
1899	52,011	6,685	12.85	—	—	—	29,966	57.61	7,256	13.95	4,058	7.80
1909	120,775	12,865	10.65	—	—	—	39,876	33 02	40,517	33.55	12,793	10.59
1919	361,520	75,788	20.96	2,957	15,490	4.28	55,753	15.42	181,602	50.23	20,161	5.58
1929	987,708	244,894	24.79	46,457	143,727	14.55	55,940	5.66	428,219	43.35	34,359	3.48
1930	927,447	224,628	24.22	43,170	164,443	17.73	49,208	5.31	372,498	40.16	34,201	3.69
1931	894,608	219,957	24.59	35,116	176,437	19.72	42,446	4.74	336,967	37.67	26,704	2.98
1932	819,997	195,386	23 83	26,332	170,905	20.84	43,836	5.35	294,750	35.95	22,433	2.74
1933	861,254	195,622	22.71	25,346	180,623	20.97	48,977	5.69	316,439	36.74	23,775	2.76
1934	895,636	206,337	23.04	28,162	182,433	20.37	53,855	6.01	335,353	37.44	26,373	2.94
1935	965,790	219,280	22.70	31,025	207,537	21.49	55,813	5.78	360,061	37.28	27,853	2.88
1936	1,068,570	231,344	21.65	33,817	239,650	22.43	56,082	5.25	413,874	38.73	30,927	2.89
1937	1,183,440	251,624	21.26	39,381	268,136	22.66	65,308	5.52	458,770	38.77	35,321	2.98
1938	1,165,015	245,580	21.08	39,961	270,471	23.22	64,580	5.54	446,664	38.34	30,826	2.65
1939	1,237,840	260,463	21.04	40,320	295,142	23.84	68,521	5.54	468,566	37.85	35,036	2.83

[a] Blended at refineries.

[12] Source: Prior to 1919, from the United States Bureau of the Census; 1919 and later, from the United States Bureau of Mines.

salt, and potassium salts, which are now being produced or developed, while the gas helium is extracted from natural gas for use in lighter-than-air craft, such as dirigibles. It has been announced recently that a satisfactory rubber substitute is now being manufactured from petroleum.

Marketing

Domestic trade. The petroleum industry is one of the few in which the product, from the raw-material stage to the wholesale marketing of the finished article, may be carried out by a single organization. This has not always been the case, for the early refiner was rarely a producer

TABLE XI

REFINED OIL PRODUCTS OF THE UNITED STATES DOMESTIC DEMAND VERSUS EXPORTS FROM 1928 TO 1939[13]
(in Barrels; 000 Omitted)

Year	*Domestic Consumption*				
	Gasoline (motor fuel)	*Kerosene*	*Lubricants*	*Gas and Fuel Oil*	*Total Principal Refined Products*
1928	338,881	36,235	23,168	383,974	782,258
1929	382,878	36,032	23,609	415,156	857,675
1930	397,609	34,736	21,589	368,531	822,465
1931	407,843	31,358	19,924	334,668	793,793
1932	377,791	33,221	16,614	308,157	735,783
1933	380,494	38,493	17,152	323,705	759,844
1934	410,339	44,234	18,484	340,371	813,428
1935	434,810	47,645	19,661	366,723	868,839
1936	481,606	51,428	22,323	410,641	965,998
1937	519,352	54,972	23,323	442,355	1,040,002
1938	523,003	56,360	21,233	407,320	1,007,916
1939	552,557	60,501	23,613	462,891	1,099,562
	Exports				
1928	53,412	22,034	11,023	44,427	130,896
1929	62,059	20,022	10,860	39,151	132,092
1930	65,575	16,884	9,935	36,450	128,844
1931	45,716	12,712	8,128	29,231	95,787
1932	35,438	11,044	6,851	19,994	73,327
1933	29,321	8,959	8,218	20,563	67,061
1934	24,686	9,781	7,660	28,605	70,732
1935	30,613	6,651	8,499	28,948	74,711
1936	28,646	6,936	8,691	34,883	79,156
1937	38,306	8,886	10,975	45,433	103,600
1938	50,109	7,504	9,417	47,561	114,591
1939	44,559	8,243	11,981	49,511	114,294

[13] *Ibid.*

and, as a rule, sold his product through established retail outlets for other merchandise. With the automobile, however, came a big demand for the raw material from which gasoline is made.

In order to guarantee the supply of his own raw material to meet this demand, the refiner was forced into the producing end of the business. Once he had an assured supply of crude oil, he then attempted to secure for himself equally assured outlets for his product in a fiercely competitive market. This he accomplished by establishing local bulk stations, to which his product moved by tank car or barge. From these points, distribution of gasoline and kerosene was made by tank truck or wagon to retail outlets, where the products were sold from pumps.

Wholesale prices of oil products are quoted in the trade journals currently. Lubricating oils other than motor oils and greases are usually sold either as package goods or in barrels. On the other hand, gas oil, fuel oil, and asphalt are sold in bulk to buyers and, quite frequently, directly from the refinery. The pressure of production of raw material is felt more rapidly in the oil industry than in other industries because of its complete integration and the rapid losses by evaporation of its most important product, gasoline. Consequently, there has been a tremendous extension of the retail facilities for marketing petroleum products, until they now include 226,000 filling stations, 182,000 other scattered outlets, and 26,000 bulk and storage plants, with the result that the public can secure at convenient points anywhere in the United States a standardized product at competitive prices.

Export trade. The export market in 1939 took approximately 10 per cent of the petroleum products produced by the refineries in the United States. It will be noted, however, that lubricating oil and kerosene constitute a much greater proportion of the exports than of the domestic trade.

Formerly, a large proportion of the product sold for export was packed in cases, but bulk distribution facilities are now installed in all the larger markets of the world. The cost of distribution to foreign markets has been high, owing mainly to the low density of consumption in foreign countries. The per capita consumption of the United States is something over 8 barrels of petroleum per annum, while that of China is but $\frac{1}{100}$ of a barrel per annum. This vast difference in intensity of consumption naturally increases the cost of petroleum products in the export market.

Operations in this market have been confined to relatively few companies, because of the specialized personnel necessary to cope with problems peculiar to it—such as the handling of customs, foreign exchange, duties on special products, and the specialized questions which arise in connection with the shipment of such products with marine equipment. There is a marked tendency among foreign countries to establish preferential duties on crude oil against refined products, so as to force refining within the country of destination, and also a tendency to set up petroleum monopolies, such as those in Spain, or to insist on special licensing for importation, as in France. These are intended partly as revenue measures, partly as protection against shortage in case of war. As a rule,

these special forms of regulation have increased the cost of distributing oil and in the end are paid for by the ultimate consumer, either in an increase in price or by a lowering of quality.

Petroleum and its derivitives being prime materials used in war and peculiarly susceptible to attack, it is difficult to understand the tendency in foreign countries to insist on the establishment of refineries for military purposes, as they are particularly vulnerable to attack from the air. It would seem preferable in such cases that the refineries be far removed from the centers of military operations, nearer to the sources of crude supply. Storage can be concealed underground.

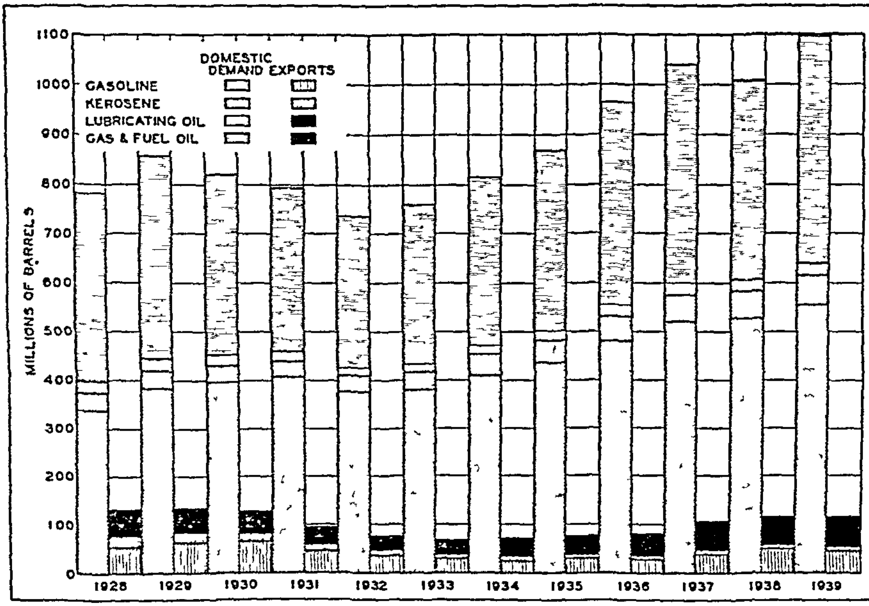


FIG. 6 Refined oil products of the United States, 1928-1939. domestic demand versus exports.

Competition. The marketing of refined oils is fiercely competitive. In writing of the sale of gasoline, S. A. Swensrud[14] states:

> The general level of gasoline price is fundamentally determined by the interaction of gasoline demand and crude oil supply. The close correspondence of actual gasoline prices and price changes among the leading companies is the result of economic necessity. . . . Suppose, therefore, that today a certain leading company cuts the price two cents, no other representative company could afford not to cut unless it were willing to risk losing much of its business.

As he points out, gasoline prices are posted conspicuously and the buyer is mobile, so that on any wide spread of price he takes his business elsewhere.

[14] "Economics of Distribution in the Oil Industry," in *Transactions of the American Society of Mechanical Engineers*, Petroleum Division (1931), p. 609.

Three grades of gasoline are marketed as a rule. They differ mainly in their octane rating—that is, their ability to operate a high-compression motor without knocking.

Financing the Industry

The investment. It is probable that the investment in the oil industry at the present moment exceeds $12,000,000,000 and that the number of investors is close to 3,000,000. In general, the industry has financed itself by plowing back its own earnings or by sale of common stock. Obligations of fixed interest-bearing type, such as bonds, are issued by oil companies for funds to be used for the erection of refining plants, the building of pipe lines, or the acquisition of tank cars or ships, the revenue from which can be calculated with certainty in advance. The companies listed on the New York Stock Exchange on April 30, 1940, showed the following distribution of securities: stocks, at market value, $4,294,000,000; bonds, $631,304,000. In general, the successful companies have been able in the past to finance their expansion by the sale of additional stock to their stockholders or out of earnings. However, because of the imposition of proration in the producing phase of the industry in the United States, by which the return on producing properties has been spread out over a long period of time, there is a tendency at present for oil companies to increase the amount of bond financing.

Government participation in the industry by financing is to be found in certain foreign countries, but this usually takes the form of government companies such as the "Yacimientos Petroliferous Fiscales" of Argentine and the Spanish monopoly. A rather unusual case was that of the British Government's participation in the Anglo-Persian Oil Company for the purpose of guaranteeing a fuel oil supply for the navy.

Employees

It is estimated that there are approximately 1,000,000 employees engaged in the petroleum industry. The latest figures available covering 1937 are shown in the accompanying table. It will be noted, of course, that the larger proportion of these employees are concentrated in marketing. As an industry, outside of the marketing branch, the production, transportation, and refining of petroleum are highly mechanized; and the production per man has been increasing continuously, although recent figures are not available. On the wage side there has been a continuous increase in the weekly earnings. For instance, the average weekly earnings in the refining end of the industry rose from $31.73 in 1923 to $34.91 in 1938, despite the change to the 40-hour week during this period. From 1933 to 1938 the average hourly earnings in the refining branch of the industry rose from 65.1 cents per hour to 97.8 cents an hour, and in the production branch from 64.7 cents per hour to 84.5 cents per hour, while the average earnings in manufacturing industries

TABLE XII

EMPLOYMENT IN THE PETROLEUM INDUSTRY FOR 1937

Branch of the Industry	*Source of Data*	*Average Number of Employees*
Drilling[a] and production:		
Salaried employees[b]	Estimated from Bureau of Mines 1935 Census	8,500
Wage earners[b]	Bureau of Mines 1937 Census	121,371
Total for drilling and production		129,871
Contract drilling[a], total	Estimate	16,000
Natural-gasoline plants:		
Salaried employees	Estimated from Bureau of Mines 1935 Census	1,100
Wage earners	Bureau of Mines 1937 Census	9,429
Total natural-gasoline employees		10,529
Petroleum pipe lines:		
Salaried employees	Estimated from 1937 ICC Pipe-Line Report	2,666
Wage earners	Estimated from 1937 ICC Pipe-Line Report	26,933
Total pipe-line employees		29,599
Marine transport, total	Estimate	12,000
Refining:		
Salaried employees	1937 Census of Manufactures	15,268
Wage earners	1937 Census of Manufactures	83,183
Total refining employees		98,451
Marketing[c]		
Wholesale, total	Estimated from 1935 Census of Distribution	124,798
Retail, service stations	Estimated from 1935 Census of Distribution	402,804
Retail, indirect[d]	Estimate	182,000
Total marketing employees		709,602
Total Petroleum-Industry Employment		1,006,052

[a] Company drilling employees are included in drilling and production figures; contract drillers are employees of independent contractors, for whom few reliable data are available.
[b] Wage earners, classified as "workers" in the Bureau of Mines 1937 Census, are believed to include some clerical-field employees; salaried employees are estimated low to allow for this.
[c] Includes proprietors, except for indirect retail employment.
[d] This is a rough estimate of the number of wage earners selling petroleum products at the 182,000 country stores, parking lots, garages, and other nonservice-station outlets for gasoline and lubricating oil. Estimated at 1 petroleum worker per outlet.

as a whole rose from 46.3 cents an hour to 64.6 cents per hour. It will be noted, too, that the oil industry has the highest weekly earning and hourly wage rates of any manufacturing industry listed by the United States Bureau of Statistics; nor is this all, for the petroleum industry as a whole is notable for the stability of its employment and also for its freedom from important strikes and industrial disturbances. Inside the industry real efforts are made by the companies employing labor to improve the condition of their employees by first-aid training courses, by pension and insurance systems, and in some cases by stock allotments, although during the depression the latter were found difficult to administer satisfactorily. All of this may be summed up as indicating that the oil industry as a whole treats its employees as well as those in any other single industry.

Important Legislation Affecting the Industry

Laws relating to defining oil ownership. The legal systems of the world as they treat of petroleum may be divided into two groups: (1) those in which the petroleum in the subsoil belongs to the owner of the surface; and (2) those in which it is reserved to the government. In general, in the United States, the oil has belonged to the owner of the surface, but in recent years the Government, in alienating title to lands, has in most cases specifically reserved title to the oil that may be below such lands. Most of the South American countries belong in the second class (with the exception of Columbia, where oil on some lands belongs to the owners of the surface), as do about almost all European countries. Early in the history of the American industry, questions arose as to the drainage of oil from one man's land by the wells on the land of another. In order to prevent interminable litigation, certain Pennsylvania courts held that oil was not the property of an individual until it was reduced to possession by being brought to the surface, and compared it to wild game. This is the much discussed Law of Capture. As a result of these decisions, a jurisprudence grew up which, in defining the rights of individuals, imposed upon the holder of a lease the obligation to drill offset wells and thus to protect that lease from drainage of oil by the operations of others. These obligations are now firmly entrenched in American law, with the result that an oil pool once opened was usually developed as rapidly as possible because of the legal obligations of the various leaseholders either to drill offset wells or to forfeit leases, and the oil produced was thrown on the market regardless of the demand for it at the time. It had not appeared entirely feasible in the past to estimate the amount of petroleum under each piece of land or to determine each man's right to that oil, so the court generalization above mentioned might be justified. Nevertheless, it set a premium on rapid drilling and has been one of the forces compelling overproduction.

With the enormous increase in operations as a result of the great demand for oil and the development of new methods for prospecting, it became clear that, unless some curb were put upon production, the situa-

tion would become chaotic. Oil could be produced in some fields for a very few cents a barrel, while in others costs were as high as $1 a barrel If the price were allowed to drop to the point where flush oil alone could be produced to satisfy the demand, it would have meant the abandonment of a large proportion of the producing wells in the United States, with a corresponding loss of the oil they would have yielded; and while this might have led to a temporary decrease in the price of petroleum products, in the end it would have worked toward an increase in the average price and a loss of a large amount of reserves, which could only be produced from wells already drilled. Furthermore, the extremely rapid recoveries led to a host of wasteful practices and decreased materially the ultimate recovery from oil pools. As this became increasingly evident, the various states stepped in and developed conservation laws allocating the production between individuals and fields. These laws have two separate and distinct bases: first, a reasonable division of the market between the various producers; and, second, the conservation of oil in the ground by the regulation of the rate of production to increase the amount of oil to be commercially recovered from each field. It was found after some experimentation that, by cutting down the production of wells and producing the oil over a period of time, the fields would yield greatly increased quantities of oil, and so laws which first were enacted to prevent wasteful production methods on the surface turned out in the end to have a substantial engineering basis, which leads in the direction of the conservation of our irreplaceable oil reserves.

Laws tending to conserve petroleum. Outside of the proration laws briefly outlined above, legislation has been passed in most states to prevent wasteful methods of petroleum production. These methods prohibit, for instance, the blowing of gas into the air; the manufacture of carbon black, except under certain specific conditions; the pollution of streams by oil; the maintenance of proper conditions underground by the cementing of oil casing; and the repair of faulty casing, which might permit the invasion of water into oil sands.

Pipe-line regulations. The pipe lines are regulated by special laws and, in the case of the interstate lines, come under the jurisdiction of the Interstate Commerce Commission. Pipe-line rates are usually scrutinized by this commission, and pipe-line companies are, as a rule, obligated to take oil intended for transportation from any pool ratably among producers in that pool.

Taxation. Table XIII shows an estimate of the taxes paid by the petroleum industry during the years 1936 to 1938. It is to be noted that the petroleum industry pays about 11 per cent of the taxes levied in the United States, and this does not include taxes paid by owners of oil securities on their income. It is also to be noted that these earnings are not dividends, which, of course, are very much less than the actual earnings shown. The natural result of this tremendous tax burden is to increase the cost of petroleum products to the consumer; and it is interesting to note that, while the gasoline tax—the largest consumer of taxes in this class—in 1920 added only 0.3 per cent to the cost of fuel for

automobiles, in 1938 when the motorists drove up to the pump, 38.7 per cent of the money they paid to the dealer went to direct taxes.

The foreign attitude. The foreign legislator has taken a political attitude toward oil. [illegible] by the [illegible] of the war in these latter days and the [illegible] of [illegible], he has given to oil a peculiar significance not possessed by any other product. Consequently, much

Table XIII

PETROLEUM TAX BILL FOR 1936 TO 1938[11]

Tax	Total Taxes Paid		
	[illegible]	[illegible]	[illegible]
State gasoline taxes	[illegible]	[illegible]	[illegible]
Federal [illegible]	[illegible]	[illegible]	[illegible]
[illegible] property taxes	[illegible]	157,8[illegible]	13[illegible]
Income taxes, federal, state, [illegible]	[illegible]	9[illegible]	70,000,000
[illegible] taxes, state and local	[illegible]	[illegible]	25,000,000
[illegible]	31,2[illegible]	31,31[illegible]	[illegible]
[illegible]	11,[illegible]	12,5[illegible]	10,1[illegible]
Capital stock taxes	7,110,000	7,000,000	6,000,000
[illegible]	6,5[illegible]	7,2[illegible]	7,002,[illegible]
[illegible] for petroleum [illegible]	[illegible]	5,500,000	5,000,000
State petroleum inspection fees	5,250,000	[illegible]	[illegible]
Local gasoline taxes	[illegible]	5,000,000	[illegible]
[illegible]	4,300,000	4,073,000	[illegible]
Corporation franchise [illegible]	1,080,000	1,000,000	[illegible]
Sales, privilege, and occupational taxes, state and local	2,250,000	2,300,000	[illegible]
Federal tax on crude [illegible]	[illegible]	[illegible]	[illegible]
State excises on [illegible] automotive equipment	185,000	212,500	[illegible]
Total Petroleum Taxes	$1,2[illegible],173	$1,315,487,7[illegible]	$1,18[illegible]

* Some items are [illegible] and subject to revision.

foreign legislation has been restrictive and has resulted in the very [illegible] development and very incomplete exploration of the resources of a [illegible] part of the world. The fairly liberal laws passed in Venezuela [illegible] the twenties and early thirties led to a rapid development of the [illegible] in that country. A change in the oil laws of Colombia in 193[illegible] in rapid increasing interest in that country. The effect of [illegible] legislation and the acts of the Mexican Government on Me[illegible]

[11] Authority: American Petroleum Industries Committee

tion are too well known to need comment. It would seem, in general, that the best interests of any country are served by general oil laws with rather liberal premiums on the development of oil in the country. Undeveloped reserves are useless in time of war; they are merely frozen assets.

Important Companies in the Petroleum Industry

The breakup of the Standard Oil Trust in 1911 resulted in the organization of a number of separate companies, which are generally known as the Standard Oil group. At the time of dissolution, many of these companies were of local significance only, while others were left with unbalanced facilities, some with crude-oil production and no refineries and some with refineries but no production. Four of these companies developed to international importance: the Standard Oil of New Jersey, the Standard Oil of New York (now the Socony-Vacuum), the Standard Oil of Indiana, and the Standard Oil of California. The Standard Oil of Indiana has confined its activities to the United States outside of the Pacific Coast, having sold its interest in the Pan American and Transport properties in Mexico and Venezuela to the Standard Oil Company of New Jersey. The Standard Oil Company of California entered the international markets by developing production in Bahrein and Arabia, and entering into a partnership with The Texas Company for purposes of marketing and producing in the Far East.

The two most important foreign units, the Royal Dutch Company, with large holdings in the Netherlands East Indies, and the Shell Trading and Transport Company of London, were combined through a partnership agreement to form the Bataafsche Petroleum Maatschappij and the Anglo-Saxon Petroleum Company. These companies operate throughout the world. Their American subsidiary is the Shell Union.

Other important American oil companies. Of the companies outside the Standard group, The Texas Company is the only one marketing its own brands in all the important world markets. It operates in the United States, has interests in Colombia, Bahrein, and Arabia, and is actively exploring for oil in other parts of the world. It also is a large purchaser of crude oil for refining. The Gulf Oil Corporation is a large producer of crude oil in the Central United States and in Venezuela, with markets on the Eastern seaboard and in the interior of the United States. The Consolidated Oil Corporation is a producer in the United States and has carried out extensive explorations in foreign countries; it now markets throughout the United States.

Large companies which are locally of great importance are the Union Oil Company of California; Phillips Petroleum Company, the largest producer of natural gasoline, and Skelly Oil Company in the Mid-Continent; and the Continental Oil Company in the Rocky Mountains, Mid-Continent, and California. A large foreign corporation of great importance is the Anglo-Persian, operating large oil fields in Persia and refining and marketing in Europe, the Near East, and India. It is closely affili-

ated with the Burma Oil Company. These companies are also known as the major companies.

Organization of a Typical Oil Company

The large integrated oil company is usually organized on the line and staff basis, as is shown on the accompanying diagram (Figure 7). The operating head is usually the president and the various important departments of the company, which cover producing, refining, transporting, and marketing activities, are headed by vice presidents. Financial matters, as far as general accounting is concerned, are usually handled by a comptroller, while the treasurer handles banking matters, collections, and credits. In some companies the president is aided in his control of operations by a budgeting office, which forecasts receipts and expenditures, and determines the rate at which plant and equipment shall be run. In the operation of large companies, this is a complicated and technical matter, requiring the best brains available. Another important activity that may come directly under the president's supervision is a research department, which keeps the corporation in touch with the various developments and phases of the industry, and which experiments with various technical processes looking toward improvement in plant and operating technique.

Future of the Petroleum Industry

The most pressing problem that faced the oil industry in the last decade was the adjustment of production to demand As stated under the section on legislation, the basic law on petroleum in the United States practically compelled the rapid development of new fields as they were discovered. Once this development took place, the oil was produced as rapidly as possible from each lease to prevent the wells on the neighboring lease from draining the property. As a result of development of the technique of oil finding, the speed of discovery was immensely increased, until in recent years the supply brought to the surface has exceeded the demand and oil, though relatively a perishable commodity, has been stored in large quantities. Sporadic efforts to reduce production failed to accomplish any tangible result, because of the lack of coördination between the various producing regions. This difficulty now seems to have been remedied by legislation in some of the important producing states, and there seems to be a reasonable probability that production will be kept closely in line with demand. Overproduction had disastrous results on the efficiency of the industry in that it promoted wasteful practices.

The question of waste due to overproduction would not have been so serious were it not for the grave doubts concerning the adequacy of the supply of crude oil in the United States. While it is true that there is an abundance of oil at present, even the most optimistic estimates do not predict a supply of oil from wells now drilled which will be adequate for

Figure 7.

ORGANIZATION CHART FOR A LARGE OIL COMPANY

Stockholders → Board of Directors → Chairman of the Board / Executive Committee → President →

- Producing Department (Vice-President)
  - Engineering (Construction)
  - Operating
    - Oil Lease
    - Gas Lease
    - Natural Gasoline Plants
  - Development
    - Drilling
  - Exploration
    - Geological (Geologists)
    - Land & Lease
      - Lease Men
      - Scouts
  - Accounting
- Crude Oil Purchases & Sales (Vice-President)
- Pipelines (Usually operated by subsidiary)
- Refining Department (Vice-President)
  - Terminals (Superintendent)
  - Skimming Plants (Superintendent) Complete Refineries
    - Fullers Earth Plants
    - Cracking Equipment
    - Lubricating Plant
    - Asphalt Plant
    - Case & Pack Div
      - Lumber Mills
      - Can Plants
  - Chemists & Engineers—Research & Plant Control
  - Accounting
- Marine Department (Manager)
  - Operating
    - Ship Movements
    - Rates, Routing & Charters
    - Equipment & Repairs
      - Tank Ships
      - Barges
  - Accounting
- Domestic Marketing (Vice-President)
  - Statistician
  - Marine & Government Sales
  - Gasoline & Lubricating Sales
  - (Sales Manager)
    - Aviation Sales
    - Bulk Stations
      - Tank Wagons & Trucks
        - Filling Stations
        - Agencies
  - Asphalt Sales
    - Road Oil
    - Roofing Sales
  - Fuel Oil Sales
  - Engineering (Construction)
  - Advertising
  - Accounting
- Export Department (Vice-President)
  - Foreign Sales (Agencies)
  - Foreign Sales (Subsidiaries)
  - Shipping Division
  - Engineering (Construction)
  - Foreign Terminals
  - Accounting
- Treasurer
  - Banks & Banking
  - Credit & Collections
- Statistical Section
  - Budget Control
- Comptroller
  - General Accounting
  - Auditing
- Secretary
  - Records
- Legal Department—(General Counsel or Vice-President)—Legal Staff
- Purchasing Department—(Chief Purchasing Agent)
- Insurance Department—(Manager)
- Company Publications—(Editor)—Public Relations
- General Research—(Director)
- Employment & Service—(Manager)

national uses for more than a score of years; and such estimates do not, as a rule, include large amounts of oil which must be produced by relatively costly methods and which cannot be sold at the average price that has obtained during the last 10 years. There are probably still vast undiscovered supplies. It is also to be noted, however, that there are possibilities that oil may be extracted from shale and coal, and that these deposits may be used to eke out petroleum supplies for a long time. If, however, any large part of our supplies came from such sources, it would involve the creation of a mining industry and would draw even more heavily on the man-power of the nation than the coal industry does at present, besides resulting in a much higher price for petroleum products From every rational viewpoint, there is no doubt that the industry should, by wise use and efficient methods of production and handling, conserve as much oil as possible for the future, both to preserve an essential raw material for the nation and to preserve and extend its own life.

A question that may well be raised for the industry in the future is the possibility of a change from gasoline as its most important product to some other product, such as has taken place in the last 30 years in the change from kerosene to gasoline. If such a change is in the offing, it is not perceptible at present, and we can look forward to the continued supply of motor fuel as one of the industry's principal functions. It is probable, however, that the introduction of catalytic cracking and hydrogenation methods has opened the door to a new chemical phase of development, in which the list of products developed by the larger refiners will multiply and the larger units will become primarily great chemical factories producing many new products.

One of the most reassuring factors in the future of the industry is the continued increase in demand. A great deal has been written about the saturation point for automobiles in the United States, and it would appear that, with a ratio of automobiles to population of close to 1 to 5, that point will soon be reached, and that the growth in automobile registrations in the future will run more nearly parallel to the growth in population. This means a slowing down in the increase of consumption of gasoline. However, the possibilities of aviation as a source of consumption are only beginning to be realized, and it is probable that this will make a market for large additional quantities of gasoline.

It is to be remarked that an automobile is something which almost every man craves, as it gives him the ability to get from place to place independently in the shortest possible time, and while the ratio of automobiles to population is high in the United States, it is relatively low at the present time in every other country in the world. This condition is due in part to standards of living in foreign countries, which are lower than in the United States, and in part to the lack of roads on which automobiles can run. Possibilities for the increase of oil consumption in foreign countries is therefore very great. In this connection, it might be remarked that one of the tendencies of the future will undoubtedly be for the United States to produce a smaller proportion of the total production of the world than it has in the past and, as time goes on, for other

nations—particularly such producing countries as Russia, Persia, Iraq, Arabia, Colombia, Venezuela, Argentine, and the Netherlands East Indies —to produce a larger and larger proportion of the world's petroleum. This does not necessarily mean that the amount of oil produced in the United States will lessen, and we can still look for an increase in consumption and production to continue here; but it does mean that the increase in consumption by other countries will be supplied from foreign sources. We may well look forward, therefore, to a continuation of the rapid growth of the industry.

16

The Coal Industry

Early History of Coal

Origin. Whether we adhere to the peat-bog theory or the drift theory of the geological formation of coal, we take the profuse vegetation of the Carboniferous Age as its genesis. The vast duration of this epoch is evidenced by the presence of more than 100 coal seams, one above another, in certain areas, each representing thousands of years of forest growth. In the intervening strata, usually of sandstone or shale, are found a wide diversity of vegetable and animal fossils.

Discoveries. The earliest mention of coal occurs in the Proverbs of Solomon: "As coals are to burning coals, and wood to fire, so is a contentious man to kindle strife."[1] Probably King Solomon, with his wide knowledge of minerals, was familiar with the bituminous-coal deposits of Syria, then a part of his kingdom.

The first authentic use of coal was by the soldiers of Hadrian (76 to 138 A. D.), Emperor of Rome, who visited Britain about 119 A. D. He caused a wall to be built, 70 miles in length, to secure the Roman provinces from incursions by the Caledonians; and near Manchester, England, coal cinders have been found in the ruins of this wall, as well as shallow pits from which the coal was taken.

About 1238, a colliery was opened at Newcastle, England. "Sea coale" was gathered along the outcrops, and the product was burned in open braziers with much smoke and soot. As late as 1600, two small vessel loads supplied the entire demand of London; and in 1665, following the plague, Charles II forbade the use of coal, under penalty of hanging or imprisonment, in the belief that its smoke was injurious.

Late in the thirteenth century, Marco Polo described the coal found in the province of Cathay in China and commented:[2]

> There is a kind of black stone which is dug out of the mountains like any other kind of stone and burns like wood. These stones make no flame, except a little at the beginning when they are lit, like charcoal,

[1] *Proverbs* 26:21.

[2] Benedette, L. F., *The Travels of Marco Polo* (New York: Viking Press, 1931), p. 160.

> and by merely remaining red hot they give out great heat. . . . Hence they make great use of those stones not only because they are cheaper, but because in this way they can save much wood.

Dr. Ashley, State Geologist of Pennsylvania, says that very probably the coal beds at Fushun, Manchuria, were operated as early as 1100 B. C. to furnish coal for copper smelting.

Not until the middle of the eighteenth century were the Welsh coal fields opened, wooden rails installed to facilitate underground haulage, and the early prejudices against coal overcome The invention of the steam engine by Watt in 1765, the development of the iron industry, and the invention of the puddling forge in 1784 constitute the basic factors in the growth of the coal industry in the Old World.

In 1679, Father Hennepin, a Franciscan friar and a member of an exploring party under Robert Cavalier, was canoeing down the Illinois River, hoping to reach the Mississippi. At a point near what is now the city of Ottawa, Illinois, he noted a black ledge, which he marked on his map as a "Cole Mine."

The American Indians, at an uncertain date, had learned the value of "stone coal," now known as anthracite; and in 1766, a committee of six Indians made complaint to the governor of Pennsylvania that a certain John Anderson had been stealing "fire stones" from their pits. As a result, a survey was made in the Wyoming Valley, and these pits were marked on the map as "stone coal." About the same time, a report was made by Joseph Tilghman to William Penn of an easily accessible bed of coal. In spite of these discoveries, coal was not widely used. In 1776, however, a consignment of anthracite coal was teamed to the Revolutionary army, stationed at Carlisle, Pennsylvania.

The first use of coal for metallurgical purposes occurred in 1778, when anthracite was used in making nails by Judge Jesse Fell of Wilkes-Barre.

In 1791, a hunter named Philip Ginter discovered an outcrop of anthracite coal at Summit Hill, near Mauch Chunk, Pennsylvania. The following year the Lehigh Coal Mine Company was formed. This firm was succeeded by the Lehigh Coal and Navigation Company, the oldest coal company in America, and still in operation.

Early distribution and transportation. For many years, the producers had great difficulty in selling their product. Colonel Shoemaker, of Pottsville, hauled nine wagons of anthracite coal to Philadelphia, where he ultimately succeeded in selling two loads and gave away the remaining seven. The two that were sold were purchased by a wire-works plant, whose workmen, after trying for a day and a night to make the coal burn, walked away in disgust, leaving the furnace door open. Left to itself, the fire box reddened; and when the workmen returned, the whole furnace was aglow.

As a market developed for the new fuel, it was first transported by wagons and then by boats constructed from timber taken on the property, and sold after unloading. In 1817, a millwright named Josiah White

conceived the idea of wing dams and "bear traps," by which the boats could be more safely floated. He then built a gravity plane known as the "switchback" between the mines and the river.

In 1820, total shipments amounted to 365 tons. In 1825, the demand for anthracite coal reached 28,000 tons per year, and the timber requirements for building boats denuded 400 acres per year. In 1829, the Lehigh Canal was completed to Mauch Chunk; and in 1838, it was extended to White Haven, from which point a railroad connected the Lehigh Canal with the Pennsylvania State Canal, on the Susquehanna River. Thus the return of boats was provided for, many wrecks were avoided, and the first transportation system for the movement of coal both East and West was established.

The cost of transportation on the railroad section was 4 cents per ton-mile, as against 1 cent per ton-mile on the canal. In 1863, the coal company was authorized to abandon the canal above Mauch Chunk and to extend its railroad to the mouth of the Lehigh River, where rail connection to New York City was available.

This action marks an epoch in transportation history, the point where railroads were substituted for canals in freight haulage. Although since that time the cost of railroad transportation has decreased to approximately one tenth the original cost, the cost of canal transportation has remained approximately the same.

Growth of the bituminous-coal industry. We have traced briefly the growth of anthracite coal and must now turn our attention to the history of bituminous coal. After Father Hennepin's discovery, in 1679, the next historic record in bituminous coal falls in 1750, when a boy hunting crawfish on the James River bank above Richmond, Virginia, came across a black outcrop that reminded him of coal he had seen unloaded from English ships.

Before the close of the year, the first soft-coal mine in America was in operation in the "Richmond Basin." Ultimately six great districts were opened up in the United States, and today more bituminous coal is mined per hour than was brought over from England by all the vessels of colonial days.

In 1853, coal from the Deep River field of North Carolina was shipped by boat to Green Point, Long Island (now a part of Greater New York), and was used for the manufacture of illuminating gas, at the first commercial plant for this purpose in the United States.

Bituminous-coal production became of official record in 1821, when 1,322 tons were produced. This figure grew, in the century following, to approximately 400,000,000 tons The output of bituminous coal in 1939 was 393,065,000 tons, an increase of 13 per cent over 1938 The coal industry made substantial gains, in common with general business activity, during the latter half of 1939, and the total output for the year was 27 per cent above the record low of 1932, although 27 per cent below the 534,989,000 tons of 1929.

Types of Coal

Coal may be divided into the following general classifications: peat, lignite, cannel, bituminous, anthracite, and graphite.

These classifications merge into one another and thus form subgrades, such as semibituminous, semianthracite, and so forth. Since 1927, concerted effort has been applied by a Sectional Committee on the Classification of Coal, sponsored by the American Society for Testing Materials, and embracing 23 national associations, scientific societies, and Government bureaus. in an effort to "develop a plan for the classification of coals based upon such chemical and physical characteristics as would make the plan most readily adaptable to industrial and commercial use on a national scale."

Representatives of producers, consumers, and the general public were included in the group, and subcommittees on use classification, scientific classification, marketing practice, and nomenclature were created. This work is in progress. and will ultimately afford a definite and acceptable standard.

For the present, however, we shall continue to use the current classification employed by Bayley and others.

Peat. Peat occurs in bogs, or sphagnous moss, consisting of living plants, dead partially carbonized plants, and a brown jellylike mass from 80 to 90 per cent water. It owes its preservation to the presence of humic acid.

Lignite. Lignite, or brown coal, is partially carbonized wood, jointed but friable, occurring in true beds like coal but of a much later geological age.

Cannel. Cannel coal is a compact, noncoking bituminous coal, with a dull luster. It does not soil the fingers in handling, lights easily, and burns with a clear, bright flame. It is used for open-grate fires and in the manufacture of gas.

Bituminous. Bituminous coal is black and lustrous, and shows woody structure under the microscope. It shatters into irregular lumps and may be either coking or noncoking.

The decomposed gelatinous constituents of a coal determine its coking quality, which is usually computed by its hydrogen-oxygen ratio, estimated on a moisture-free basis, in relation to its fixed carbon percentage. Bayley says:

> When $\frac{H}{O} > 59$, the coal is usually coking, provided it contains no more than 79 per cent of fixed carbon in pure coal. Coals containing over 79 per cent of fixed carbon are coking only when the ratio between the volatile carbon and the fixed carbon is greater than one-tenth, though they may give good results in by-product ovens.

Anthracite. Anthracite coal is hard, bright, and brittle, low in volatile matter, and conchoidal in fracture. It is so hard that it may be turned in lathes, and vases and other ornaments can be made of it.

Graphite. Graphite is a soft carbon of little commercial significance. It is not in ordinary circumstances combustible. It is, however, really a metamorphosed coal, the result of alterations probably originating in magmatic cooling. Graphite occurs in the older crystalline rocks, such as gneiss and schist. A large deposit of this kind is found in Rhode Island.

Coal Fields

Peat is produced commercially in the States of California, Connecticut, Florida, Georgia, Illinois, Indiana, Maine, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, North Carolina, and Pennsylvania; and peat beds are intermittently worked in Oregon, Washington, Wisconsin, Iowa, Ohio, and Virginia. Potential deposits are found in Vermont, Delaware, South Carolina, and Texas. Peat is occasionally imported from Canada, Germany, and Holland.

Lignite occurs in vast deposits in the states west of the Mississippi River, notably in North Dakota, Montana, Wyoming, Colorado, and Texas. There are also active operations in Louisiana and high-grade deposits in Mississippi. Some of these approach subbituminous coal. Although the lignites underlie many thousands of square miles, their development and utilization has been slow because of sparse settlement and lack of industries in those areas, and also because of the availability of higher-grade fuels at reasonable costs.

Cannel coal occurs in Alabama, Arkansas, Illinois, Indiana, Iowa, Kentucky, Michigan, Missouri, Pennsylvania, Ohio, Texas, Utah, and West Virginia. In many of these states, the deposits are in the form of a small basin, and are operated for local domestic supply. The principal producing states are Pennsylvania, Kentucky, Ohio, West Virginia, Missouri, and Texas. The largest known reserves are in Kentucky and Texas. Production figures are usually included with those of bituminous coal.

The bituminous-coal fields of the United States, after a conference of geologists and the United States Geological Survey, have been arbitrarily divided into six major regions, as follows:

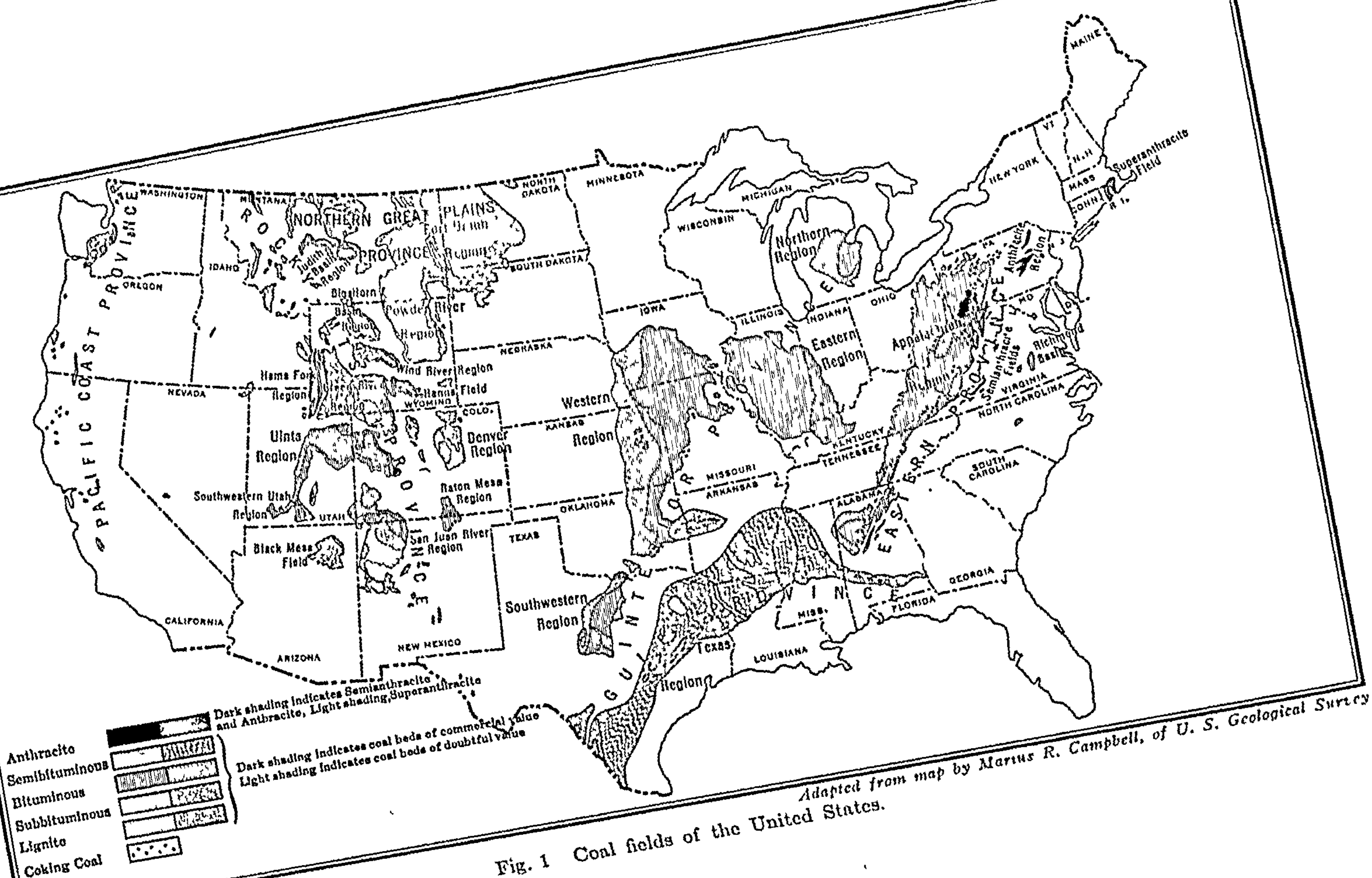
(1) The Eastern province, which includes all the bituminous areas of the Appalachian region, the Richmond Basin, and the Deep River and Don River fields of North Carolina.

(2) The Gulf province, which also includes the lignite fields mentioned above.

(3) The Interior province, which includes the Mississippi Valley and the coal reserves of Michigan. This is often commercially subdivided into northern, eastern, western, and southwestern regions.

(4) The Northern, or Great Plains province, which, in addition to the lignites previously mentioned, includes the bituminous fields of eastern Wyoming and eastern Montana.

(5) The Rocky Mountain province, which includes the coal fields of Utah, Colorado, and New Mexico, western Wyoming, and western Montana.



Adapted from map by Marius R. Campbell, of U. S. Geological Survey

Fig. 1 Coal fields of the United States.

(6) The Pacific Coast province, which includes California, Oregon, and Washington.

Anthracite coal occurs principally in an area of 496 square miles, in 9 *counties of Pennsylvania. Of these 9 counties,* 5—Lackawanna, Luzerne, Schuylkill, Northumberland, and Carbon—produce 96 per cent of the total output. The 4 less important producing counties are Susquehanna, Dauphin, Columbia, and Sullivan.

The only other known deposits of economic value in the United States are in Colorado, New Mexico, and Arkansas. Operations in these states, however, only produce about 100,000 tons annually.

The Merrimac or "valley" coal of Virginia, frequently referred to as anthracite, is in reality a good grade of semianthracite and is the only substitute east of Arkansas for Pennsylvania anthracite. The product is similar to Lykens Valley coal from Pennsylvania.

Tonnage reserves. In 1918, the United States Geological Survey estimated the total quantity of good peat in the United States to be:

Region	*Tons of Coal*
Northern	11,053,000,000
Atlantic coastal	2,701,000,000
Other	72,000,000
	13,826,000,000

Later, at an International Coal Conference, Dr. M. R. Campbell, of the United States Geological Survey, presented the following data on United States coal reserves and depletion:

	Number of Tons
Lignite and subbituminous	1,935,665,000,000
Bituminous and semibituminous	1,486,464,000,000
Anthracite and semianthracite	22,423,000,000
Grand Total	3,444,552,000,000
Total production including 1925	16,819,181,148
Estimated loss in mining	8,409,000,000
Total Exhaustion	25,228,181,148
Original tonnage	3,444,552,000,000
Produced and lost	25,228,181,148
Reserves, January 1, 1926	3,419,323,818,852

With reference to world reserves, Dr. Thom, of Princeton University, estimates this present reserve to be in the relation shown in Table I.

Reference to Figures 2 and 3 graphically portrays both anthracite- and bituminous-coal production in the United States from 1820 to the present time.

Mining

Anthracite mining. Anthracite is now produced from three sources: mines, old culm banks, and rivers that drain the anthracite regions. The

TABLE I

WORLD COAL RESERVE BY COUNTRIES

Country	*Lignite and Low-Rank Bituminous Coals*	*Gas, Coking, and High-Rank Bituminous Coals*	*Anthracite Coal*	*Total of All Grades*
United States	53%	29%	4%	45%
Canada	20	10	1	18
Europe	7	29	9	11
Africa	3	3	2	3
Asia	14	22	84	20
Oceania and Australia	2	6	.2	2
Mexico, Central, and South America	1	.3	.2	1
	100%	100%	100%	100%

majority of the anthracite beds are folded, or steeply pitched and frequently faulted. The usual method of mining is to sink a shaft at the lowest point of the strata, so that a sump, or drainage pit at the bottom, may collect the water for pumping.

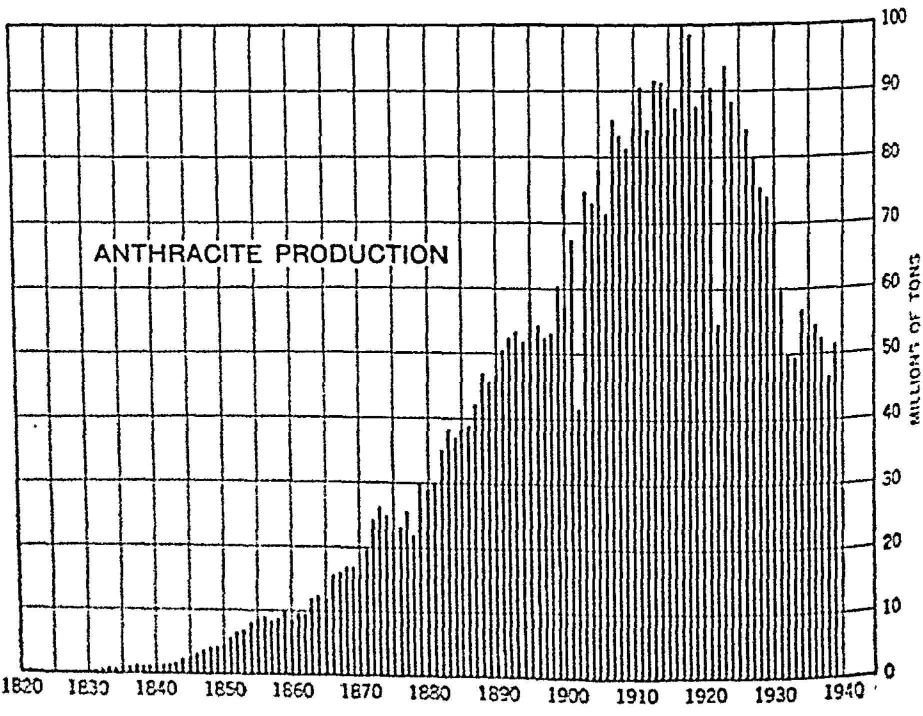


FIG. 2 Anthracite-coal production in the United States from 1820 to 1939.

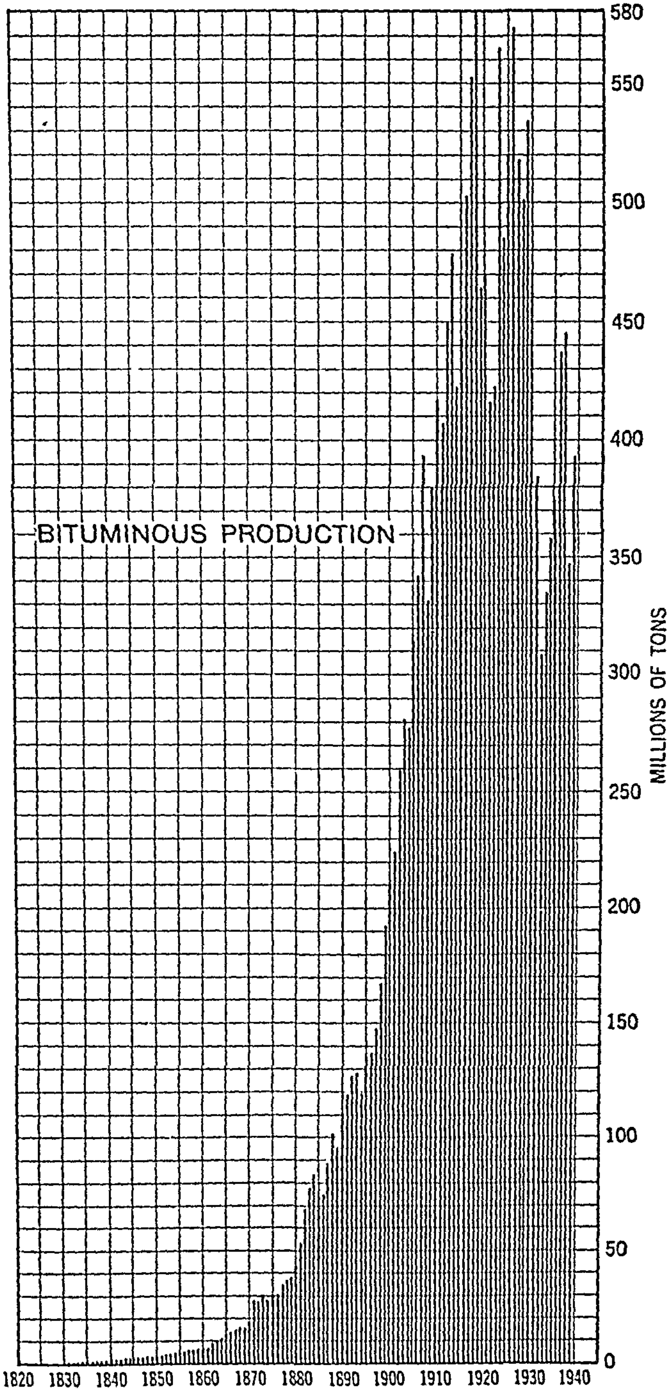


Fig. 3. Bituminous-coal production in the United States from 1820 to 1939.

Headings, like tunnels, are driven out horizontally, at various levels from the shaft, cutting across the inclined coal seams; and the coal is then removed as the breasts, stopes, or rooms are driven upward from the heading. The coal, sliding down through chutes, is loaded into pit cars, hauled to the shaft, hoisted to the surface, passed through the breaker—where it is broken and cleaned by a dry-picking, washing, or some other process—sized, and loaded on railroad cars.

The percentages of recovery are now so much larger than they were 40 years ago that, notwithstanding increased annual production, the life of the region is still estimated to be about 100 years.

Forty years ago only 40 per cent of the coal in the ground was recovered. It is now estimated that from 65 per cent to 75 per cent of the coal in the ground, and a great deal of that formerly left through inefficient mining operations, is being recovered. In fact, one mine that was "abandoned" 50 years ago has produced more coal since its operation was resumed than it did before.

The Susquehanna River and its branches, having flowed past the anthracite workings since their inception, have carried many millions of tons of fine anthracite coal down the valley, and have deposited it in riffles and bars. It is estimated that, in recent years, nearly 1,000,000 tons annually are recovered by dredging. In 1939, dredging operations in the Lehigh River produced 62,134 net tons; in the Schuylkill River, 67,539 net tons; and in the Susquehanna River, 574,187 net tons—a total of 703,860 net tons, at a value of $746,000.

Certain of the anthracite properties are also operated by stripping the overburden, with steam shovels or drag-line scrapers, and removing the exposed coal by open-cut methods. Over 2,000,000 tons per year are thus produced.

Illicit coal. A survey by the Pennsylvania Department of Mines shows that, in the latter part of 1939, 2,500 illicit or "bootleg" holes were in operation in the Pennsylvania anthracite region, employing 9,000 men.

The estimated illicit production of coal in the region in 1939 was between 3,500,000 and 4,000,000 tons, or about 8 per cent of the total anthracite output.

Volume and value. In 1939, the total value of anthracitic production at the source was $187,175,000, and the gross revenue accruing to railroads was $102,180,268. This production was 51,487,000 tons, or a gain of 12 per cent over 1938.

Mechanical loading. The percentage of total deep-mined production of anthracite loaded mechanically continued to increase. In 1939, the 11,773,833 tons so loaded were 27.7 per cent of the total underground output, as compared with 26.6 per cent (10,151,669 tons) in 1938 and 25.1 per cent (10,683,837 tons) in 1937. The total tonnage loaded mechanically underground increased 16 per cent from 1938 to 1939; hand loading advanced 10 per cent.

Bituminous mining. Bituminous coal ordinarily lies more nearly horizontal than anthracite, although pitching seams, when encountered, are mined in the same way as anthracite.

Bituminous coal may be mined either by slope, drift, or shaft; and, when opened up, the development may be:

(1) By the "room-and-pillar" method, in which solid blocks of coal are left to support the surface until the extreme boundaries of the property are reached, when they are drawn, by the process called "robbing," in systematic fashion back toward the shaft or mouth of the entry.

(2) By the "long-wall" method, either advancing or retreating, in which the coal is mined along a continuous face, either in constantly widening circles around the shaft or by driving a circumferential face like the rim of a wheel, with haulways like the spokes, converging at the shaft in the center. In long-wall mining the roof is supported along the spoke-like haulways by timber cribs filled with "gob," or rock. The segments between are allowed to cave.

In both methods, the idea is so to prosecute and maintain the work as to utilize the weight of the overlying strata, called "roof pressure," in breaking down the coal with a minimum of explosives, and at the same time to avoid falls of roof rock over uncontrolled areas.

The coal is conveyed or hauled to the head of the shaft or mouth of the entry, where it passes over a tipple and is cleaned, sized, and loaded on railway cars.

In southern Illinois, western Kentucky, the tristate area of Missouri-Kansas-Oklahoma, and in the Rocky Mountain and Great Plains regions, there has, of late years, been developed a substantial tonnage of coal removed by stripping, or open-cutting. This tonnage now amounts to about 20,000,000 tons per year.

The advantages of stripping coal are its almost complete extraction, the fewer men required, and the decrease in danger to the men. The process suffers, however, from bad weather and the necessity for absolute removal of all overburden that would otherwise increase the ash content. Strip coal also tends toward higher moisture content, owing to its proximity to the surface.

The particular method of underground working is determined by the position, thickness, and nature of the coal seam. Where the area has been squeezed or faulted, or where "cut-outs" or "horsebacks" occur, special methods may be necessary. If bands of iron pyrites, often called "sulphur balls," are abundant, they not only deteriorate the coal but are of themselves serious handicaps to cutting or shearing. Sedimentary bands or "partings" of slate or clay sometimes occur and must ordinarily be removed to maintain the necessary purity or low ash content of the coal. It is when these partings occur in thin laminations, breaking with the coal and adhering to it, that most difficulty is encountered in their removal.

In early days, when more than 50 per cent of the coal was left in the ground and when slack (or fine) coal was wasted, coal was shot "on the solid." This practice not only broke up the coal with an excess of fines but shattered the roof rock, making it dangerous to operate under, and caused the removal of many tons of rock that undercutting and careful

shooting would have left intact. Also, because of many "blown-out" shots, this method was considered highly dangerous, and it is now forbidden by law in most states.

As mechanical methods of mining were evolved, machine picks, or "punchers," operated by compressed air, were used to undercut the coal. Since the cuttings were thus removed, a smaller amount of explosives was necessary to bring down the face of coal, which fell into a pile of large lumps.

The increasing use of electricity and the ease of its application led to chain machines, by which an endless chain of cutting bits, operating around a projecting "cutter bar," may be used either for a horizontal undercut, for vertical shearing, or for cutting out an intervening band or parting. The fine cuttings are colloquially known as "bug dust." When the cut has been made in clear coal, this dust is loaded out and included in the slack or fine coal. When it is made in rock, it is shoveled aside into the "gob," or waste.

Wherever possible, this waste of partings, roof rock, or stone dust is packed away underground to avoid the cost of hauling it to the outside and dumping. But where the sulphur content or nature of the coal is such as to cause heating by spontaneous combustion, or mine fires, it must be expeditiously hauled out and deposited away from the outcrop. This waste is known as the "gob pile," and may frequently be seen smoking and smouldering for many years.

Mechanization. The latest development is in mechanizing the loading process. Mechanical loaders and scrapers put the coal into mine cars without hand labor. Conveyors of various types and lengths reduce the labor of hand shoveling and serve the further purpose of eliminating the gathering process by delivering the coal into trips of mine cars. The adaptation of machinery to the loading has completed the mechanization of all mining operations, from the solid face to the railroad cars on the surface.

Mechanized loading of coal increased, within 10 years, from 2,000,000 tons per year to 50,000,000 tons in 1930. This represented an increase of approximately 50 per cent a year, until at the present time more than 10 per cent of the entire bituminous-coal production of the country is from completely mechanized operations. In Illinois 70 per cent, in Montana over 60 per cent, and in Wyoming over 50 per cent of the output is loaded mechanically.

The underground production cut by machines during the year 1938 amounted to 87.5 per cent of the total output.

Lignite mining. Lignite is mined in the same manner as bituminous coal. Because of its weaker structure, more timbering is necessary, and the workings are usually driven narrower. Moreover, being a "younger" coal, the overlying strata are frequently less rigid, although some lignites are sufficiently mature to be mined on the same scale of operations as bituminous coal.

The Bureau of Mines reported that there were 212 active lignite mines in the United States in 1938. These mines employed 2,019 men and pro-

duced 2,997,921 net tons of lignite. These figures do not include the smaller mines producing less than 1,000 tons annually, nor the small quantities of subbituminous coal some times known as "black lignite."

Producing peat. Peat is plowed or thrown up into windrows so it can drain and air-dry. After this process, it is used in its fibrous state or compressed. Its value for fuel is limited to those areas far removed from coal or wood.

The total production of peat in the United States in 1939, as reported by producers to the Bureau of Mines, was 55,438 short tons, valued at $362,066.

Haulage. Haulage in small mines is still effected by small-bodied mules. A few still use rope haulage, either the "endless" or "tail" system; but all the large mines use electric locomotives. In some cases, small units with an electric cable, fed out from and gathered on a reel at the back end of the locomotive, go up into the working places and pull out the loaded cars to the main haulway, pushing empty cars to be loaded back into the headings, or faces. Some mines use storage-battery locomotives for this gathering service. Still others use mules for gathering the cars and hauling them to the "lieway" or central assembling point, where the heavy motors haul them in trains to the tipple or to the foot of the shaft for hoisting.

Power. Coal mines are now using annually about 2,500,000,000 k.w.h. In 1920, approximately three fourths of the total power consumed in mining was produced at the mine. In 1930, the situation was reversed, and three fourths of the power used came from public-utility sources. This change was brought about by the fact that, as power requirements grew, necessary water for condensation was lacking at many mines. With a 72 per cent boiler efficiency, 1 pound of steam requires 109 pounds of water, at 70 degrees F., and 1 ton of coal at 15,000 B.T.U. will make 18,000 pounds of steam. Thus we see that, to utilize 1 ton of coal properly, would require from 900 to 1,000 tons of water for condensation purposes. Plant efficiency at large central producing units has also brought the coal consumption to approximately three fourths of 1 pound of coal per k w h.

Drainage. Drainage, wherever possible, is effected by gravity—in drift mines, by opening the mine at the lowest point in the outcrop; in slope and shaft mines, by collecting the drainage water in a "sump" and removing it by siphons or pumps.

Ventilation. Ventilation is maintained by fans, either exhaust or force type, the uniform distribution of air being accomplished by brattices, regulators, over- and undercasts, and trapdoors. It is an established rule that fresh air must reach the workmen by the most direct route, carrying accumulated gases and smoke away from them to the second outlet. In most states, 100 cubic feet of air per man per minute and 200 to 300 cubic feet of air per mule per minute are required. Many states also require reversible fans, so that, in the event of an accident, the air current may be thrown directly to other parts of the mine. This

also permits temporary reversal of the warm air from inside to melt accumulated ice around the shaft in winter time.

It is of passing interest to note that, although air weighs only 8/100 of a pound per cubic foot, the average coal mine exhausts more tons of air per day through its workings than it extracts tons of coal, and certain large anthracite collieries pump 16 tons of water for every ton of coal raised to the surface.

Size of coal beds. The largest coal mine in the world is the New Orient operation in Illinois, which is a shaft mine having a rated capacity of 5,500,000 tons per year. Among the thick beds of coal in the world are the Mammoth anthracite bed, which is over 100 feet thick, and the Roland bed in Wyoming, which is locally 98 feet thick and at least 40 feet thick over many square miles. Dr. Ashley states that, under exceptional conditions, coals as thin as 6 to 8 inches have been mined, and a considerable production is yielded by seams 12 to 24 inches in thickness. Because of the cost of production, however, at the present time seams less than 36 inches thick are rarely operated.

The average depth of United States bituminous mines is 262 feet. The average distance of the working face from the shaft is half a mile.

Coal consumption. The late John Hays Hammond observed that, in the 100 years from Waterloo to the Marne, the white population of the world increased threefold, while the use of coal and oil increased 75-fold.

In 1821, the total production of coal was 1,322 tons; in 1840, it was 2,000,000 tons, or .12 of a ton per unit of population; in 1860, it was 14,000,000 tons, or .46 of a ton per unit of population; in 1880, it was 71,000,000 tons, or 1.42 tons per unit of population; in 1900, it was 270,000,000 tons, or 3.53 tons per unit of population; in 1920, it was 608,000,000 tons, or 6.24 tons per unit of population; and in 1939, it was 444,552,000 tons, or 3.40 tons per unit of population.

By-Products

The many and varied by-products of the coal family are shown in Table II.

Over 220 direct by-products are shown here. The majority of them are derived from tar, which, together with gas, gas liquor, and coke, are the prime substances recovered. In general, it may be said that the by-products of coal yield valuable contributions to chemistry, dyestuffs, and medicine. Nitrated coal is a new material for paints and varnishes.

Cannel coal is used for enriching coal gas and, in the days before the development of the petroleum industry, was a source of oil.

Lignite yields similar combinations. It is also used in its powdered state to preserve eggs, as a mixture in the filtration of cane juice, as a decolorizer, and an ingredient of hollow tiles, affording porosity after burning. When carbonized lignite is purified with hydrochloric acid, it is a competitor of vegetable carbons in sugar manufacture; and after the addition of dilute ammonia, it becomes highly gas-adsorbent, retaining 145 volumes of chlorine gas. Hence, as a catalyzer, it is of great value in

TABLE II

CHART OF COAL PRODUCTS

(The Koppers Construction Co.—Pittsburgh, Pa.)

- COAL
  - Gas
    - Fuel Gas
      - Cement Burning
      - Steel Furnace
      - Refractory Burning
      - Gas Engines
      - Glass Manufacture
      - Bakeries
      - Steam Rising
      - Industrial Use
      - Rubber Vulcanizing
      - Blend with Other Gas
      - City Gas
        - Refrigeration
        - Cooking
        - House Heating
      - Rubber Vulcanizing
    - Illuminating Gas
      - City Gas
      - Street Lighting
      - House Lighting
      - Factory Lighting
      - Industrial Lighting
    - Cyanogen
      - Alkali Cyanide
        - Gold Recovery
        - Gold Plating
        - Photography
        - Insecticide
      - Silver Plating
      - Silver Recovery
      - Ferricyanide
        - Blue Printing
      - Prussian Blue
        - Wall Paper
        - Dyes
        - Paint Pigment
      - Neutral Blue
        - Pigment
      - Sulpho-Cyanides
        - Artificial Silk
        - Cotton Finishing
        - Mordant
        - Resins
        - Photography
        - Vulcanized Rubber
    - Naphthalene
    - Sulphur
      - Sulphuric Acid
      - Insecticide
      - Fungicide
      - *Chemical Industry*
      - Agriculture
  - Ammonia
    - Pyridine
      - Alcohol Denaturant
      - Disinfectant
      - Rubber Cement
      - Insecticide
      - Plastic
      - Solvent
    - Aqua Ammonia
      - Chemical Agent
    - Anhydrous
      - Paper Manufacture
      - Refrigeration
      - Chemical
    - Ammonium Chloride
      - Dyes
      - Galvanizing
      - Dry Batteries
      - Pharmacy
    - Nitrous Oxide
      - Laughing Gas
    - Ammonium Nitrate
      - Dyes
      - Explosives
      - Fertilizers
    - Ammonium Carbonate
      - Baking Powder
      - Wool Scouring
      - Rubber Goods
      - Smelling Salts
    - Ammonium Phosphate
      - Fertilizers
    - Nitric Acid
      - Dyes
      - Fertilizers
      - Explosives
    - *Ammonium* Persulphate
      - *Oxidizing Agent*
      - Bleaching
      - Photography
    - Ammonium Sulphate
      - Fertilizers
      - Explosives
      - Dyes
      - Fire Proofing
    - Ammonium Alums
      - Dyes

CHART OF COAL PRODUCTS (*Continued*)

(The Koppers Construction Co.—Pittsburgh, Pa.)

- COAL (Continued)
  - Light Oil
    - Solvent Naphtha
      - Xylenes
        - Xylidines ......Dyes
        - Flotation Oil
        - Reddish-Brown Dye
        - Organic Solvent
        - Paint Solvent
        - Motor Fuel
      - Resins . . .
        - Electrical Insulation
        - Radio Parts
        - Varnish
        - Rubber Composition
        - Roofing
        - Paint
        - Stains
        - Seasoning for Paper
      - Rubber Solvent
      - Linoleum
    - Toluene
      - Nitro Toluene . . . .
        - Trinitrotoluol .....TNT—Explosive
        - Cotton Dyes
        - Toluidines ......Blue Sulphur Dyes
        - Dyes for Silk
      - Sulpho Acid ....
        - Saccharin ...
          - Medical
          - Sugar Substitute
        - Sulphone Dyes
        - Antiseptic
    - Benzaldehyde .
      - Tobacco Seasoning
      - Sodium Benzoate ......
        - Food Preservative
        - Dental Preparation
      - Benzoic Acid ....
        - Perfume
        - Food Preservative
        - Blue Dyes
        - Almond Flavor
      - Dye Stuffs ....
        - Malachite Green
        - Patent Blue
      - Medicine
      - Perfume
    - Benzyl Alcohol
      - Perfume
      - Airplane Dope
      - Jasmine Oil
    - Varnish
    - Benzene .....
      - Nitro-Benzene .. .. .
        - Aniline ....
          - Mauve Dye
          - Orange & Yellow Dyes
          - Methylene Blue
          - Indelible Pencils
        - Aniline ....
          - Aniline Salt
          - Rubber Stamp Ink
          - Acetanilide
          - Aniline Black
          - Methyl Orange
        - Diphenylamine ....
          - Anti Flash
          - Dye
        - Hydro-Quinone ....Photo Developers
        - Dinitro-Benzene ...
          - Cotton Yellow
          - Dye Stuffs
          - Bismark Brown
      - Pheno-Sulpho Acids . .
        - Water Soluble Dyes
        - Synthetic Rubber
        - Tanning
        - Plastics
      - Azo-Benzene . ...
        - Congo Red
        - Azo Dyes
      - Fuels ....
        - Gas Enrichment
        - Solvent
        - Motor Fuel
        - Airplane Fuel
      - Maleic Acid
    - Carbon Disulphide ...
      - Solvent for Rubber
      - Artificial Silk
      - Insecticide

CHART OF COAL PRODUCTS (*Continued*)

(The Koppers Construction Co.—Pittsburgh, Pa.)

- COAL (Continued)
  - Tar
    - Tar Acids
      - Phenols
        - Nitro-Phenol
          - Nitro-Phenol
            - Medicine
            - Perfumes
            - Dyes
            - Explosives
          - Picric Acid
            - Explosives
            - Medicine
            - Chemicals
            - Dyes
          - Amino-Phenols
            - Photo Developer
            - Dyes
        - Bakelite
          - Auto Parts
          - Pipe Stems
          - Billiard Balls
          - Electric Plugs
          - Insulation
          - Gears
          - Jewelry
        - Salicylic Acid
          - Medicine
          - Perfume
          - Oil of Wintergreen
          - Food Preservatives
      - Cresols
        - Bakelite
          - Radio Parts
          - Amber Substitute
          - Phonograph Records
          - Buttons
          - Beads
        - Lysol
        - Photo Developer
        - Stains
      - Carbolic Acid
      - Tar Bases
        - Quinoline
          - Photographic Dyes
          - Antiseptic
        - Heavy Bases
          - Disinfectant
        - Pyridine
          - Alcohol Denaturant
          - Insecticide
          - Disinfectant
      - Neutral Oils
        - Paint Thinner
        - Shingle Stain
        - Lamp Black
        - Motor Fuel
      - Naphthalene
        - Explosives
        - Plastics
        - Insecticide
        - Dyes
        - Moth Balls
      - Insecticides
      - Flotation Oils
    - Heavy Oils
      - Phenanthrene
        - Rosin Soap
        - Resins
      - Anthra Quinone
        - Laxatives
        - Dyes
        - Alizarin
      - Anthracene
        - Dyes
      - Carbolineum
        - Embalming Fluid
        - Fungicide
        - Wood Preservatives
      - Carbazol
        - Lubricant
        - Wood Preservatives
        - Dyes
    - Hard Pitch
      - Gas
        - Heating
      - Coke
        - Iron Heating
        - Electrodes
      - Hard Pitch
        - Fuel
        - Core Compound
        - Targets
      - Electrodes
      - Insulation
    - Soft Pitch
      - Briquetting
      - Storage Batteries
      - Roofing
      - Water Proofing
      - Paving
      - Koppax Paint

CHART OF COAL PRODUCTS (*Continued*)

(The Koppers Construction Co.—Pittsburgh, Pa.)

- **COAL (Continued)**
  - **Tar (Continued)**
    - Middle Oils
      - Phthalic Anhydride
        - Phenolphthalein
        - Indigo
        - Dyes
        - Alcohol Denaturant
      - Naphthalene ..
        - Photography
        - Dyes
        - Antiseptic
        - Lamp Black
        - Halowax
        - Tanning
      - Lycosote . . .
        - Pitch Thinner
        - Disinfectant
        - Wood Preservative
      - Disinfectant
      - Varnish
      - Flotation Oil
    - Refined Tar ..
      - Pipe Covering
      - Roofing
      - Concrete Water Proofing
      - Paving
      - Sidewalk Composition
      - Insulation
      - Paints
  - **Coke**
    - Calcium Carbide......
      - Acetylene
      - Acetic Acid
      - Cyanimid
    - Coke ....
      - Baking Powder
      - Washing Soda
      - Carborundum
      - Graphite
    - Retort Carbon
      - Electrodes
      - Carbons
    - Metallurgical Coke...... ..
      - Foundry Coke .... . .
        - Lead and Zinc Melting
        - Cupola
        - Brass Melting
      - Iron Blast Furnace
      - Lead Smelting
      - Copper Smelting
      - Electrodes
    - Gas Manufacture .
      - Carbon Dioxide ......
        - Carbice
        - Soda Water
      - Water Gas
      - Producer Gas
      - Blue Gas
    - Breeze ....
      - Briquets
      - Gas Producers
      - Boiler Fuel
    - Fuel ....
      - Steam Rising
      - Bakeries
      - Domestic
      - Power Plants

the production of carbon tetrachloride, used in chemical warfare. It is also a base of Montan wax, extracted by the use of benzol and other solvents, entering into phonograph records, adhesive greases, stove polish, and insulating and sizing materials; and for cable covering, roofing materials, and impregnating woven belts.

The United States Bureau of Mines has done a great deal of research in gas extraction and carbonization of lignites, and the reader is referred to *Bulletin 255* for full details of this potential development.

Peat is largely used as a fertilizer filler and as an adsorbent for uncrystallized residues of beet and cane sugar in the manufacture of stock feed. North Carolina peat, which is high in carbon and volatile matter, has been used for the production of tar, wood alcohol, and ammonia compounds. Peat is also used as a deodorizer of stable liquids, as an absorbent with mineral wool, and as a substitute for excelsior in packing. Combined with wax under pressure, it has been used as paving material.

Transportation and Distribution

Coal reaches the market by rail or river transportation, or a combination of both; by rail to tidewater (New York, Philadelphia, Baltimore, Hampton Roads, Charleston), and thence by steamer for coastwise export, or bunker trade; or by rail to the Great Lakes ports, and steamer to upper Great Lakes ports and Canada, and thence by rail to the Northwest.

It is estimated that from 85 to 90 per cent of bituminous production obtains all-rail delivery. Ninety-five per cent of the bunker, coastwise, and export coal passes through the ports named above. Approximately 28 per cent of the port shipments is bunker coal. This figure corresponds very closely to the quantity consumed as railroad fuel.

Certain railroads, through subsidiaries and public utilities, own and operate their own coal mines, which are commonly known as "captive" mines. Approximately 100,000,000 tons per year are thus produced.

The Lakes-rail movement to the Northwest is one of the great economic features of the industry. Of the Lakes cargo boats, 200 out of 400 are engaged in carrying coal to the head of the Great Lakes and returning with cargoes of iron ore and grain.

This movement during the summer months affords a seasonal outlet for the mines, and serves to stock the upper Lakes storages. The largest single dock at Duluth has a capacity of 800,000 tons of bituminous coal and 200,000 tons of anthracite, and another at Green Bay, Wisconsin, holds 500,000 tons. Car ferries also serve the Canadian trade.

The export business is largely dependent upon a small margin of profit, and is limited by keen competition from other countries and by freight rates to the ports. A normal amount of both anthracite and bituminous coal goes to Canada, averaging in recent years between 12,000,000 and 15,000,000 tons of bituminous and between 3,000,000 and 4,000,000 tons of anthracite. Certain states in the Northwest import approximately 500,000 tons of bituminous coal annually from Canada, because of favor-

able freight rates. Such movements of low value per unit of weight commodities are governed almost entirely by the cost of transportation rather than by tariff regulations or even cost of production.

In 1939, of practically 51,500,000 tons of anthracite produced, 11 per cent went to the New England states, 79 per cent to the Atlantic states, 5 per cent to Canada, and the remainder to the Central and Western states.

The various sizes of anthracite formerly marketed have changed greatly within the past few years. In 1939, six tenths of 1 per cent of the total production was larger than "egg." The demand for "steam" sizes has increased from 10 per cent to over 33.3 per cent.

About 500,000 tons of bituminous coal go to the West Indies, and a considerable tonnage is shipped to South America and the Mediterranean.

Total exports of anthracite coal in 1939 amounted to 2,590,000 net tons, while bituminous exports were 11,590,478 net tons. The margin of profit on this business, however, is very small, and the future of export coal from the United States depends wholly upon rail and shipping rates. In fact, the whole freight-rate structure is inextricably interwoven into coal distribution, not only with regard to the Lakes ports and export abroad, but in connection with tidewater movement to New England. The present competitive setup in the Northwest is a hang-over from changes in Illinois-Indiana freight rates, whereby other states secured an opportunity to reach hitherto prohibited areas, and this trade has never been regained by the Central field.

The average railroad freight charge per net ton of revenue bituminous coal amounted to $2.23 in 1939, as compared with $2.27 in 1938.

Between 1938 and 1939, imports of bituminous coal rose 47 per cent—from 241,305 tons to 355,115; while the imports of anthracite declined 18 per cent—from 362,895 tons to 298,153.

The average price of bituminous coal at the mine during 1939 was $2.32 per ton for prepared sizes, $2.09 per ton for run-of-mine, and $1.51 per ton for screening or slack. The average sales realization per net ton of anthracite coal on breaker shipments fell from $4.16, in 1938, to $3.85, in 1939.

Labor Statistics[3]

Anthracite. According to the Pennsylvania Department of Mines, about 93,000 men were employed in the anthracite region in 1939. The number employed in 1938, as based upon direct reports to the Bureau of Mines from operators, and including the employees of dredges and strip contractors, was 96,417.

Man-days lost because of strikes were 0.2 per cent less in 1938 than in 1937, and suspension of work due to strikes and the number of men involved also declined. Comparable statistics covering 1939 are not yet available, but there were no widespread labor disputes during that year.

[3] United States Department of the Interior, *Minerals Yearbook, 1940*, pp. 859 and 799.

According to the Bureau of Labor Statistics, average weekly earnings during 1939 ranged from a low of $17.16 in December to a high of $35.84 in May and averaged $25.52, or 9 per cent above the 1938 average. The index of employment (1929 average equals 100) fluctuated between 44.7 in July and 53 in April, and averaged 3.3 per cent below 1938. The index of pay rolls reached a low of 25.2 in July and a high of 57 in May, and averaged 3.4 per cent above 1938.

Bituminous. An average of 441,333 men were employed at the bituminous-coal mines in 1938, a 10 per cent decrease from the total of 491,864 of 1937. Statistics of men employed in 1938 represent annual averages of the number of workers on pay rolls on the days when the mines were in operation.

In recent years, a special problem has arisen in recording employment through the adoption of local "share-the-work" agreements, by which employees of a mine are divided into two crews or groups, who work on alternate days. Such agreements for "staggering" or alternating the work are not to be confused with the practice of operating both a day and a night shift, but relate rather to the division of available work between two groups of workers on the same shift, usually the day shift.

Specific inquiries regarding such agreements by the Illinois Department of Mines and Minerals, in 1938, indicated that 45 mines in that state were operating with alternate crews under "share-the-work" agreements.

The average number of days of operation at bituminous-coal mines in 1938 was 162. This represents a decline from the average of 193 days in 1937.

Data for 1938 indicate that the bituminous-coal-mine employees performed 71,325,374 man-days of labor during the year. The length of the working day in regard to hours amounted to an average of 7.02 hours per day per man.

Storage

Intermittent operation of mines is one of the great difficulties in bituminous mining. Many leading engineers believe that the development of storage would permit even production throughout the year, continuous employment, and relief of congestion on railroads during maximum demand seasons.

In the past, operators have said that storage is the duty of railroads, carriers have contended that it is the duty of the consumers, while the consumer has maintained that the producer should shoulder the burden. If this cycle could be broken, the seasonal fluctuations could undoubtedly be relieved. Tyron says: "Coal is not so much a commodity as it is a service."

If we consider storage, then, from the producer's standpoint, we find that he has the following objections to it:

(1) Added expense and risk.
(2) No assurance of transportation when needed.

(3) No advantages during labor troubles.
(4) Extra, different, and expensive equipment.
(5) Maximum storage capacity is about 50,000 tons per acre under most favorable conditions, and in the mountainous sections typical of the coal fields, the ground is unsuitable or unavailable.
(6) The operator must bear all losses and expense.

The Committee on Storage of Coal, reporting to the United States Fuel Administration, declared that 47 per cent of idle time in coal production is due to seasonal demand and 37 per cent to overdevelopment, our national production capacity being twice our consumption capacity.

The committee favored the development of storage at the point of consumption when possible, with intermediate storage when necessary. Both anthracite and fuel oil are so stored. The committee estimated that from 9 to 10 per cent of total annual consumption should be held in storage by the consumer, with a 7 per cent reserve—a total of about 16 per cent for which storage should be provided.

The objections to such storage, which must be met by the consumer, are: (1) the financial burden; (2) spontaneous combustion; (3) degradation; and (4) deterioration.

The estimated average cost of storage equipment, including fixed charges, maintenance and operating costs, interest on investment, taxes, and insurance, was given as from 50 to 75 cents per ton in large plants and from $1.00 to $1.50 per ton in small plants.

Competing Fuels and Combustion Efficiencies[4]

Competing sources of energy. While improvements in fuel technology have acted to lessen the demand for coal in the industries affected, these same improvements have constituted a defense of coal against the spread of other sources of energy into the previous markets for coal. In the electric-utility field, for example, consumption of coal has increased coincident with the development of hydroelectric projects. During the past 5 years, production of public-utility electrical energy by steam-power plants increased from 54,649,829,000 kilowatt-hours in 1935 to 85,006,941,000 in 1939, an increase of 45 per cent. Statistics of current and projected expenditures for new steam-plant construction indicate a continuation of this trend in the near future. Edison Electric Institute reports expenditures in 1939 of $70,560,000 for steam plants, and budget estimates for 1940 indicate a probable expenditure of $183,700,000, which will add approximately 1,650,000 kilowatt-hours to the total steam-generating capacity in 1940.

Despite the improvements in fuel economy in the utilities industry, the total coal consumption for power generation has continued to increase since 1933, except in 1938, when there was a 10 per cent decrease compared with the previous year, attributable to the general slump in industrial activity and total power consumption. The upward trend was

[4] *Ibid*., pp. 777-778.

resumed in 1939 with a total coal consumption of 46,223,000 tons, an all-time high record for this industry. In addition, the utilities steam-power plants used 17,423,000 barrels of fuel oil (approximately equivalent to 4,356,000 tons of coal) and 191,131,000,000 cubic feet of natural gas (equivalent to 8,310,000 tons of coal). During the past 20 years, the growth of the utilities industry has approximately offset the effect of improved fuel technology in relation to aggregate coal consumption, and the annual tonnage used has moved up and down from the low of 30,000,000 to the high of 46,000,000 as general industrial activity varied. Use of fuel oil also has followed an irregularly horizontal course during this period, but the consumption of gas in utility electric-power plants has increased from 22,000,000,000 feet in 1920 to 191,000,000,000 in 1939.

In the field of domestic heating, comparable figures are available for mechanical firing equipment only. In this category, the use of oil and gas appears to be growing more rapidly than coal, basing estimates upon sales of new equipment. Sales of oil burners for domestic use rose from 106,933 units in 1938 to 165,711 in 1939, a 55 per cent increase, whereas sales of domestic stokers (under 61 pounds per hour capacity) using bituminous coal, rose from 71,978 units in 1938 to 78,332 in 1939, a 9 per cent increase. However, this does not entirely represent the relative positions of the two competing fuels in new plants, because the oil-burner sales cover virtually all installations in which oil is used, while the sales of coal cover only mechanical stokers and do not consider new installations of hand-fired equipment. During the same period, sales of natural gas for domestic use increased from 352,949,000,000 to 367,733,000,000 feet, a 4 per cent gain (not including natural gas in mixtures sold by manufactured-gas companies).

The use of coal for locomotive fuel by railways decreased 17 per cent in 1938 compared to 1937 and came back 7 per cent in 1939, while the use of fuel oil followed an almost identical course, decreasing 13 per cent in 1938 and increasing 3 per cent in 1939. The consumption of railroad fuel varies with the fluctuations in volume of traffic. The use of Diesel fuel increased rapidly, rising from 25,470,248 gallons in 1937 to 34,842,982 in 1938 and 48,754,423 in 1939. In the aggregate, however, Diesel fuel constitutes as yet only about a quarter of 1 per cent of the total railroad fuel.

Statistics for 1939 show that the use of coal and oil by railroads, electric-utility power plants, and steamships exceeded that in 1938 by 10 per cent, while oil consumption increased 7 per cent. In the same period, consumption of natural gas by all industrial, commercial, and domestic consumers increased 7 per cent.

Trend in fuel efficiency. Since the First World War period, improvements in the technology of fuel application have contributed to a continuing decline in the demand for coal from industrial uses. Although the effect of such improvements is cumulative from year to year, the rate of decline is smaller in recent years as the remaining margin of possible increase in fuel efficiency becomes progressively less.

The Class I steam railroads reduced the average coal consumption by

coal-fired locomotives from 117 pounds per 1,000 gross ton-miles of freight service in 1938 to 115 pounds in 1939. For all railroad freight, including oil-burning and electrical locomotives, the average energy consumption converted to coal equivalent has reduced from 115 pounds per 1,000 gross ton-miles in 1938 to 112 pounds in 1939. During the same period, public-utility power plants lowered the average fuel consumption from 1.41 to 1.39 pounds per kilowatt-hour. In the iron and steel industry, the average consumption of coke in iron blast furnaces was reduced from 1,801 in 1938 to 1,778 pounds in 1939 per net ton of pig iron produced, representing a drop from 2,583 9 to 2,547.3 pounds of coking coal per net ton of pig iron for 1938 and 1939, respectively.

Improvements in combustion practice among domestic consumers and small industrial and commercial establishments also are helping to decrease the aggregate volume of fuel consumption. Furthermore, increasing economy in combustion methods is being supplemented by improvements in space-heating methods and by progress in building construction and insulation. Figures for the consumption of fuel, by kind and quantity, for 1939 follow:[5]

Number of establishments reporting fuel consumption	169,790
Anthracite coal	5,015,857 net tons
Bituminous coal	137,771,432 net tons
Coke	35,115,357 net tons
Fuel oils, including crude and gas oils (in barrels of 42 gallons)	133,773,524 barrels
Gas:	
Natural	881,830,178,000,000 cubic feet
Manufactured	1,288,727,385,000,000 cubic feet
Mixed	24,536,692,000,000 cubic feet

In a freight-rate hearing before the Interstate Commerce Commission, E. J. McVann testified that, in 1930, oil had supplanted 92,000,000 tons of coal, and natural gas had supplanted 30,000,000 tons per year—a total of 122,000,000 tons.

Thus we see competition, freight rates, wage scales, and labor conditions, combined with increased combustion efficiency, confronting a greatly overdeveloped industry.

Dr. Thom, of Princeton, says:

> Man's ability to control the stored energy of coal and oil is therefore at once the distinguishing characteristic, and the basis, of modern civilization, and the events of recent history are reflections either of improvements in the methods of using the mineral fuels, or of nationalistic intrigues and struggles involving the control of one or both of these mainsprings of industry and keys to economic and military power.

Health and Safety[6]

The accident rate per million man-hours of exposure among men employed at coal mines in the United States during the calendar year 1938

[5] United States Department of Commerce, *Business Series* (May, 1941), No. 4.

[6] United States Department of the Interior, Bureau of Mines (September, 1940), No 279

was slightly more favorable than in the year 1937, the 1938 rate being 84.4 as compared with 85.9 in the preceding year, according to reports furnished by mining companies to the Bureau of Mines, United States Department of the Interior.

The total number of men employed in and about the mines was 541,528, a reduction of 48,328. The total volume of labor performed was 621,000,000 man-hours, which, on the average of 7.04 hours per man per day, resulted in 88,000,000 man-days of work. Each employee averaged 163 days of employment, or 1,147 hours during the year. Accidents caused 1,105 deaths and 51,314 nonfatal injuries. The fatality rate per million man-hours in 1938 was 1.78, only slightly higher than the rate of 1.74 for 1937. The nonfatal injury rate was 82.6 in 1938, a slight improvement when compared with the previous year's rate of 84.1.

During 1938, 6 major disasters occurred—that is, disasters in each of which 5 or more men were killed. Four of the disasters were in bituminous mines and 2 in Pennsylvania anthracite mines, all of which resulted in the death of 84 men. Five of the disasters were caused by explosions of gas or dust, and one by a fall of rock.

There is every reason to expect that, as education along safety lines advances, working in coal mines will be as safe as in any other major industry.

In general, the coal-mine worker has good health. Nearly all coal mines are well ventilated, and workers are occupied in relatively pure and circulating air, with temperatures and humidity almost ideal, since very few coal mines have working-place temperatures in excess of 80 degrees F., and not many in excess of 70 degrees F.

These conditions are stable and constant; hence the underground coal-mine worker is subject to the fluctuations of surface conditions to only a slight extent, if at all. Moreover, the underground worker in coal mines is subject to no conditions that may affect his health, other than in a few isolated instances when he may be exposed to breathing dusts that induce miners' asthma. Coal mining entails the expenditure of considerable physical effort that may in time affect the heart, but ill-health is not common to the coal-mining fraternity.

Legislation Affecting the Industry

During the past 10 years, the coal industry, like many others, has been a victim of economic conditions and the general depression of 1930. Many of the 13,500 coal-mining companies of the United States were forced to close their mines, and this situation caused great hardships on the miners and their families. The past 10 years have seen a great number of Federal bills introduced in both the House and the Senate for the purpose of rectifying the inequality in the coal-mining industry. Prior to that time, there was little direct Federal legislation affecting the industry, although many bureaus and commissions had been established by the Federal Government to supervise and regulate commerce. The Federal Trade Commission, for the correction of inequitable trade prac-

tices, and the Interstate Commerce Commission, for the regulation of rail transportation, are the major Government bureaus. The Geological Survey and the Bureau of Mines handle matters specifically pertaining to minerals and the prospecting and development of public lands.

Revenue legislation, such as income-tax laws, the work of the Department of Labor in promoting harmonious relations between employer and employee, and the promotion of foreign trade by the Department of Commerce—all bear relation to the industry.

The Food and Fuel Control Act of 1917. This act led to wartime control of man power, production, priority in delivery, transportation facilities, and prices, for the duration of the First World War.

Postwar legislation. After the First World War, legislation consisted of two acts, both taking effect in 1922. The first of these provided for a Federal Fuel Distributor, to coöperate with the Interstate Commerce Commission in the distribution of railroad cars and "to prevent the sale of fuel at unjust and unreasonable prices" because of a prolonged strike that had resulted in fuel shortage.

The other act provided for the establishment of a Coal Commission, to make a thorough study of conditions in the industry. The reports of this Commission covered a wide range of subjects, including all the major phases of the industry, and was accompanied by a series of recommendations for action. Among these were continuous fact-finding, publicity, and regulation through the powers of the Federal Government over interstate commerce. The commission insisted that the public interest placed limitations on the rights of owners of coal lands, operation, mine workers, carriers, and dealers.

The Guffey Coal Act of 1935. For many years, the coal industry has suffered from overproduction and ruthless competition, which resulted in constant price-cutting wars and the demoralization of the coal industry. This created unfavorable social and economic conditions that affected capital and labor alike, and many members of Congress felt that some type of legislation would be necessary to solve the problems of the coal industry.

From 1930 to 1935, a constant stream of bills was introduced before the House and the Senate, and it was not until 1935 that the Guffey Coal Act became law. This bill provided for the coöperative marketing of bituminous coal, levied a tax of 15 per cent on the sales price at the mine, with a 90 per cent drawback to the producers who complied with the provisions of the "Bituminous Coal Code," and created a National Bituminous Coal Commission.

The Bituminous Coal Act of 1936. This act reënacted the provisions of the Guffey Coal Act of 1935, with the following major changes:

(1) It provided for a National Bituminous Coal Commission composed of 7 members instead of 5.

(2) It levied a sales tax of 1½ per cent on all coal disposed at the mine and an additional tax of 13½ per cent on coal sold in Interstate Commerce by producers in complying with the coal provisions (in place of the 15 per cent tax with a drawback of 90 per cent).

(3) It provided that the minimum prices for coal and regulations for the industry shall be "proposed" rather than "established" by the district powers.

(4) It omitted the specific provisions that prices and regulations approved by the commission "shall be binding upon all code members within the district."

(5) It contained a general declaration of policy to the effect that labor shall have the right to organize and bargain collectively, and that "yellow-dog contracts" shall be illegal.

The Bituminous Coal Act of 1937. This later act is a rewriting of the Guffey Act of 1935, which was held unconstitutional in the Carter v. Carter Coal Company, 298 U. S. 238. The act declares the necessity of regulating prices and unfair methods of competition in order to promote interstate commerce in bituminous coal, and to remove the burdens and obstructions therefrom. The following important changes are effected by the new bill:

(1) The National Bituminous Coal Commission is increased from 5 to 7; two of whom are to be experienced bituminous coal-mine workers and two experienced producers.

(2) The excise tax on coal sold in interstate commerce, in lieu of being 15 per cent of the sale price at the mine, with a drawback of 90 per cent for code members, is to be 1½ per cent for code members, plus an additional 13½ per cent for noncode members.

(3) District boards (of the same 23 producing districts as in the original act), instead of establishing minimum prices and reasonable regulations incidental to the sale and distribution of coal subject to review by the commission, are authorized merely to propose prices or regulations to the commission.

(4) The commission, as a means of enforcing compliance by persons reselling coal in commerce with the prices and marketing regulations established under the code, may prescribe a licensing or registration system.

(5) In place of the provisions affecting labor relations, right to organize, collective bargaining, etc., there is substituted a general declaration of policy approving such principles and forbidding Government purchase of coal not produced in accordance with those principles.

(6) Price-fixing provisions are applied to intrastate commerce when there exists an unjust discrimination against interstate commerce.

(7) A new separability clause is added, stating precisely that invalidation of one provision of the act or of the code shall in no way affect other sections or paragraphs.

The National Anthracite Act of 1937. Title I of this act (expiring 4 years after approval) establishes in the Department of the Interior a National Anthracite Commission (principal office in Philadelphia) of 5 members (2 who shall have been experienced mine workers, two producers, and a fifth with no experience in the industry), appointed for 4 years at a salary of $10,000; it provides also for a consumer's counsel A tax

is imposed on anthracite coal of 1 per cent per ton for code members, plus 19½ per cent of the sale price for noncode members.

The act prescribes an initial code applicable only to transactions in or directly affecting interstate commerce, of which any producer may become a member. For administering the code, there shall be a producers' board of 11 unpaid members (10 elected by producers and 1 selected from an employees' organization) for 2-year terms. Expenses are allocated among the code members.

The commission may prescribe minimum and maximum prices, and marketing regulations. Certain practices are named by the act as unfair methods of competition and violations of the code. Intrastate transactions unjustly discriminating against interstate commerce, are made subject to the price regulations. The act declares it the policy of the United States to recognize the right of labor to organize, bargain collectively, and so forth, and forbids Government purchase of anthracite not produced in accordance therewith. Code members are permitted to provide for coöperative marketing of competitive coal through agencies approved by the commission. District courts are vested with jurisdiction to issue injunctions to prevent interstate movement of stolen anthracite.

Title II provides for a national anthracite reserve, to consist of land and rights conveyed by owners to the United States. The surface of such lands may be used for forestation and flood control; adjacent lands may be acquired by eminent domain for similar purposes. Grantors may secure reconveyance when deemed for the best interest of the industry and consumers. The Secretary of the Interior may request grantors to take back lands and proceed to production when the supply of anthracite is insufficient to meet demands; if the grantor refuses, the Secretary may lease or convey these lands to another, paying to the original grantor any funds received.

The Coal Trade Act of 1937. This act is effective for 4 years. It creates a Federal Coal Trade Commission of 5 members appointed by the President and confirmed by the Senate for 4-year terms. The bill relates to anthracite, bituminous, and other kinds of coal.

By the act, the country is divided into 24 production districts and 13 market areas. In each production district, a coöperative association of producers may be organized for collective handling or marketing in interstate commerce (or in intrastate commerce directly affecting interstate commerce) of coal mined by them. Contracts may be entered into respecting prices, discounts, trade practices, allocation of markets, and so forth. Copies of association articles and contracts of members shall be filed with the commission.

Each association shall classify coal and shall file a statement weekly of what it believes to be the minimum fair market values f. o. b. mines. Each association, and producers not members of an association, shall file a statement of the minimum f. o. b. mine prices, or changes therein, at which coal will be offered for sale in each market area. Such data will be collected by the commission, and a copy sent to each association and producer. Each producer shall file monthly a statement showing

production costs, tonnage, and average employee earnings. This data shall be tabulated by the commission and distributed, without disclosing facts with respect to any individual producer.

The commission is directed to prevent unfair acts or trade practices, indirect discounts, preferments, and so forth, and its orders are made enforceable by the courts. Producers and coöperatives are exempted from the antitrust laws with respect to acts or omissions hereunder. Producers or coöperatives injured by any other producer or association by reason of willful violations hereof may recover threefold damages.

Recent legislation. Many of these important acts have been amended, and the Guffey Coal Act of 1937, which expired April 26, 1941, has been extended for a period of 2 years, to April 25, 1943.

Research and the Future

Research activities of the present may be divided into the following classifications:

(1) Constitution of coal and coke.
(2) Mining, safety, and health.
(3) Preparation and storage.
(4) Combustion of solid, liquid, and gaseous fuels.
(5) Gasification, carbonization, and processing of coal.
(6) Industrial analyses and tests

Dr. Fieldner, of the United States Bureau of Mines, has listed world efforts by institutions of learning, government bureaus, and scientific societies, with over 375 separate and assigned groups devoting special service to these and collateral problems.

Much of this work centers on items 4 and 5 above, since it is here that the problems of high- and low-temperature carbonization processes meet. In the original beehive oven, 1 ton of bituminous coal made 1,300 pounds of metallurgical coke. In the later type of by-product oven, 1 ton of bituminous coal produces approximately 1,500 pounds of coke, 22 pounds of ammonium sulphate, 9 gallons of tar, 2½ gallons of light motor oil, and 10,000 cubic feet of gas.

As a result, the beehive oven, originating in 1860 and in universal use until 1918, is now a matter of history, and coke which is secured as a by-product of coal, of refining petroleum, and in the manufacture of coal gas, enters into metallurgy and domestic fuel.

Many processes have been patented for the utilization of pulverized coal, for briquetting various grades of fines, for the extraction of valuable volatile oils, and for the complete gasification of coal, producing carbon monoxide and hydrogen in large quantities. Through direct combination of these gases by catalytic synthesis are produced methyl alcohol, esters, ketones, formaldehyde, and many other products.

The future of the coal industry is believed by many to depend upon the research chemist and engineer. A demand for energy is no longer a demand for coal; if it were, we must needs produce over a billion tons

per year. The National Research Council states that manufacturers are spending annually the equivalent of 1.3 per cent of their invested capital in research. The steel industry spends .4 per cent of its invested capital; the lumber industry 1 9 per cent; and the chemical industry, which includes petroleum, 2.4 per cent. Coal, upon the same scale as manufacturing, would spend $5,000,000 per year for this purpose. Only science can point the way.

17

The Iron and Steel Industry

Early History of Iron

How primitive man discovered the art of metal working is a matter of conjecture. Probably some savage built his campfire on an outcropping of that red earth—iron ore—and was mystified when he discovered that rough metallic nuggets reposed in its cooling ashes. Curiosity may have prompted him to attempt to break them open, so that he could learn their magic, and perhaps in this accidental way he learned that the nuggets were malleable. At any rate, crude tools of metal, spearheads, and other metallic articles have been unearthed which apparently were made centuries before the beginning of recorded history.

The art of extracting iron from the earth spread very slowly. Iron never occurs in a free state like copper or gold but is usually found in combination with other elements. It possesses a high melting point, and much heat is necessary to reduce ore to a usable form of iron. Without equipment and knowledge, centuries passed before there was a widespread knowledge of crude reduction processes. Then, too, no particular nation seemed to have acquired greater knowledge of the art than its neighbors. In all the ancient countries where there were iron deposits, the remains of crude furnaces have been discovered. These countries include Egypt, India, China, Chaldea, and Borneo.

About 4000 B.C. lived Tubal-Cain, a Biblical character whom Scripture mentions as an "artificer in iron and brass." The great pyramid of Cheops contained a wedge of iron, now the property of the British Museum, which was probably placed there about 3500 B.C., according to archæological records.

The iron pillar of Delhi. When the famed Iron Pillar of Delhi, India, was erected, no one knows, but it is supposed to have been about the fourth or fifth century, A.D. It is made up of several sections of wrought iron, welded together. As it is carefully guarded by the natives, who regard it with religious awe, its metallurgical story remained a secret for generations. Even to this day it is believed that only two small samples have ever been removed from this relic of the past. One sample is in the possession of the British Museum and the other is the property of the research laboratories of The American Rolling Mill Company.

Location of Iron Ores

Iron ores of varying qualities can be found in almost every country. When the Romans invaded Britain, they found the Britons making iron in crude furnaces. Germany has large deposits of high-phosphorus ores; the excellence of Swedish ores has long been well known; almost every section of the United States has its iron-ore fields; and South American ores are now looming over the horizon as a source of supply for our steel plants.

Early Beginnings of the Blast Furnace

Historians with vivid imaginations have pictured the primitive iron maker sitting before two goatskin bellows, alternately working them to deliver their scanty "blast" of air into a hole in a clay bank which served as his furnace. Charcoal obtained from trees in the surrounding forests was his fuel. Others picture him building huge fires on the highest hilltops, where brisk winds would fan his fire to a high temperature.

According to La Verne W. Spring, in *Non-Technical Chats on Iron and Steel*:

> The real forerunner of our modern blast furnace was the Catalan Forge, developed in, and named for, Catalonia, north Spain, where it originated.
>
> The Catalan and all of such crude early furnaces produced a variable kind of what we know as "wrought iron," and our modern "cast iron" did not appear until about 1350 when, with larger furnaces, an excess of charcoal, with greater heat and other favorable conditions, the Germans found that the pasty, difficult melting metal could be made to absorb carbon enough to make it easily fusible.

Other countries developed individual smelting processes largely similar in principle but different in name. All were fanned with a hand-powered bellows, for it was not until after 1770, when Watt invented the steam engine, that a strong continuous blast could be provided. As the demand was limited, these leisurely processes furnished the iron which carved the path of civilization for centuries. Refined in small quantities, the articles manufactured were nearly all forged with the repeated blows from a hammer, with frequent reheatings in the forge.

Mining the Iron Ore

Early methods of obtaining ore. Undoubtedly the early ore miner dug into the richest pockets of ore with pick and spade and transported by ox cart to his furnace the small quantities required. During the Civil War this custom still prevailed in southern Ohio and Pennsylvania, where the hills were dotted with stone furnaces presided over by some patriarch of the tribe, while his sons gathered the ore from the hillsides, charred the logs, and operated the furnace.

First production of iron in the colonies. Iron was written into the history of America long before the Declaration of Independence. In

1619, the ill-fated "London Colony" was established at Falling Creek, near Jamestown, Virginia, only to be destroyed by Indians. Apparently the first successful attempt at iron making began there shortly after 1640, under the direction of one John Winthrop, Jr. As colonization spread, ironworks sprang up; and many forged and sand-cast articles were manufactured in the colonies, the latter process having been imported from England. Pittsburgh began to loom up as a natural iron manufacturing center about 1800, and soon afterward the rich beds of Pennsylvania coking coal were tapped. The Trenton Rolling Mill rolled iron as a fireproof structural material, and cannons, cylinders, and many other articles were made in this country for the first time.

In those days the industry depended upon near-by deposits of ore for its raw material. The great Michigan and Minnesota fields had not yet been discovered; indeed their discovery would have been of little value, because no transportation facilities were available.

Two general methods of mining ores. Today Minnesota ores are known the world over. The "Mesabi range" has probably contributed more to the comfort of modern life than any of the famed gold mines. Ores are mined by two general methods, "shaft" mining and "strip" mining. When the deposits are far beneath the surface, the former method is employed; when near the sod, drift or surface mining is used.

Transporting Ore

Loading the ore boats. Giant shovels toss aside the earth and bite into the rich red ores, lifting tons at a time into waiting railroad cars. An engine chugs off with a string of cars destined for the ore dock on the lake front These cars are "spotted" on trestles high above the ore bins, which in turn are above the level of the docks. A freighter is waiting—the most economical form of transportation. These giant ore boats are simply long steel shells, with quarters for crew and machinery fore and aft. Most of these vessels can easily carry 10,000 tons of the "red dirt." Hatches are provided at regular intervals in the decking, through which pour streams of ore from the bins. In a few hours the ore boat is fading into the distance, bound for some southern lake port, where its cargo will be discharged.

Unloading the ore. Unloading is also a mechanized process. A giant crane slides down the dock like a monster spider. It reaches down into the hull with a large clamshell bucket and lifts out great quantities of ore. Soon the freighter is empty, and back she steams for another load. As the shipping season on the Great Lakes is limited to about 7 months, time is precious.

Ores from the Southern states are also being used in several steel plants, and great quantities are available.

Rail transportation. When the railroad car with its load of ore reaches the inland blast furnace, either its cargo is lifted out by a crane and deposited on the stock pile or the car is run on to a revolving bridge, clamped down, and slowly turned over. Its contents flow by gravity

into ore bins, from which it flows into the little car that transports it up the skip hoist and thence into the top of the furnace.

Making Steel

Operation of the blast furnace. The modern blast furnace is a towerlike structure of steel approximately 100 feet high and lined with fire brick. Carefully weighed raw materials are conveyed to the top by means of a "skip hoist," or elevator. There they are automatically dumped into a hopper and fed by gravity into the furnace over an inverted wedge-shaped bell, which tends to distribute them evenly. Formerly, iron ore was the chief iron-bearing material charged; now also scrap metal is used. Alternate layers of coke, iron ore, limestone, and scrap are put in as the furnace is "burdened." Air preheated in huge cylindrical "stoves" is forced into the furnace by powerful blowing engines. This causes the coke to melt the iron-bearing materials

Casting the "pigs." The molten iron settles to the bottom of the furnace, and when a sufficient quantity has collected, the clay-plugged tap hole is dug out. The old practice was to allow the liquid pig iron to run through channels in the earthen floor to a sand bed in the casting house. There small impressions, or molds, had been made in the sand, and the iron filled them. When the metal cooled, each piece was broken loose and was known as a "pig." Today casting machines are employed They function on the principle of an endless chain of molds. On one end of the machine the molds are filled; water sprays cool the pigs as they move along; and when they reach the point where the molds turn over to start on their return journey, the solid pieces of pig iron fall into a waiting car.

Still more modern and efficient is the practice of tapping the molten pig iron into a ladle and conveying it to the "mixer" for hot charging into the open-hearth furnaces.

The efficiency of blast furnaces has been steadily increased. Figures compiled by the American Iron and Steel Institute show that the average production per day's operations is 736.7 net tons per furnace.

Characteristics of pig iron. Pig iron is an intermediate material. It is brittle, has little strength, and must be further refined to remove its impurities before it can be really useful to man in the form of a finished article.

The puddling process. Methods for making wrought iron from pig iron were first evolved. Most important among these was the "puddling process," in which pig iron was melted in a small furnace and constantly stirred by the "puddler" until it was worked up into a pastelike ball of iron from which many of the impurities had been oxidized. The Aston process for puddling iron, a recent development of the A. M. Byers Company, has revolutionized this branch of the industry by introducing mechanization and a controlled process.

The Bessemer process. It was not until the closing days of the Civil War that a commercially satisfactory method, the "Bessemer

process," was developed for converting pig iron into steel. The invention of the Bessemer converter for manufacturing malleable iron and steel is accredited to Henry Bessemer, of England. Molten pig iron is placed inside an egg-shaped receptacle, called a "converter," and an air blast is then applied through small nozzles in the bottom of the vessel. No fuel is required, as the heat necessary for combustion is supplied by the molten metal. The oxygen of the air passing through the hot metal oxidizes, or burns out, the carbon, silicon, and manganese.

The open-hearth process. The Bessemer process has been gradually supplanted by the "open-hearth process," until today only 7 per cent of the steel made is produced by the former process. The open-hearth process has many advantages over the Bessemer. In the first place, the Bessemer is handicapped because the pig iron which it refines must be of an analysis within certain narrow limits. Then, too, the process cannot be controlled as easily as the slower working open-hearth furnace. and some of the impurities and harmful gases pass through and into the finished product; besides, the yield is lower than with the open-hearth furnace, which has less loss by oxidation.

The open-hearth furnace can use pig iron of a widely varying analysis, and larger percentages of scrap iron can be used as a part of the charge. Furthermore, control of the process need not be a matter of conjecture, as the melter can, from time to time, take samples of the metal for laboratory examination

The open-hearth process is the joint invention of two men, although they worked separately and in different countries. In 1860, C. W. Siemens developed the first regenerative furnace. It was his purpose to melt pig iron and purify it by burning out the silicon, manganese, and carbon by passing a flame over the bath. In France, P. and E. Martin successfully melted pig iron and steel scrap in a Siemens furnace. So good were the results that the names of Siemens-Martin were combined in referring to the invention of the process.

Description of open-hearth furnace. An open-hearth furnace is a rectangular structure of brick and steel consisting of an "upstairs" and a "downstairs." A stack is used for draft instead of air being forced in by a blast. Downstairs are the checker chambers for heating the air and the gas, so called because of the peculiar checkerwork effect produced by the manner in which the bricks are laid. Upstairs is the charging floor, or hearth, where the "bath" is purified. This part of the furnace is built of special heat-resistant fire brick. Reversible valves force the incoming air and gas to travel through their respective regenerating chambers, filled with red-hot checker brick, up through the ports and into the furnace, where they unite and burn with a very hot flame. These currents of air and gas, by the way, pass over the metal and not into it. Every 15 or 20 minutes the valves are reversed and fuel and air enter from the opposite end of the furnace. The main purpose of this reversal is for uniformity of heating. The hot, burnt gases pass out through ports at the other end of the furnace and,

on the way to the stack, preheat the checkerwork in the regenerative chamber.

Automatic control of furnaces. The modern open-hearth furnace is largely automatically controlled. An automatic pyrometer continuously records the temperature of the metal; and bells ring, or signal lights appear, whenever it is time to reverse the direction of the air and the gas currents. This instrument removes much of the guesswork from the process. For many years the gas producer for manufacturing coal gas was a necessary adjunct to the open-hearth furnace. New fuels are now being used, such as natural gas, coke-oven gas, fuel oil, and natural gas into which fuel oil has been atomized. Splendid results in

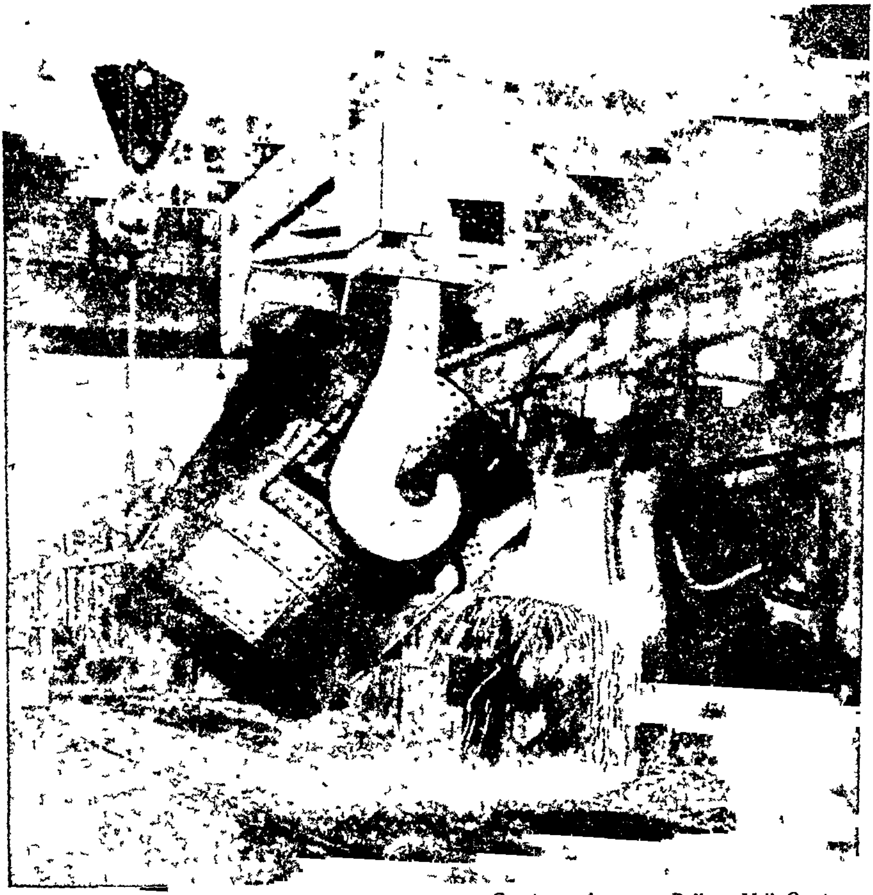
Fig. 1 The open-hearth charging machine.

lower fuel costs and decreased time for the refining operations have been obtained. Better insulation also has aided in this forward march of the open-hearth furnace, for the process depends upon the radiation of heat from the flame to the metal.

Charging the furnace. The raw material for the open-hearth furnace is charged through doors on the front of the furnace, and the refined molten metal is removed through the "tap hole" in the rear. Before a "heat" is charged, the tap hole is plugged with moist clay. Next, the "bottom-making machine" is pushed down the track, pouring a stream of crushed dolomite evenly over the bottom of the hearth. This is to protect the hearth from "burning through" and to increase the life and decrease the mainten[illegible] of the furnace.

Down the long ch[illegible]or clanks the huge charging machine,

pushing a string of "buggies," on which are mounted the charging pans full of raw materials—such as melting stock, pig iron, limestone, burnt lime, and fluxing materials. This charging machine has replaced all hand charging. It is almost as deft as a human being. On it is perched the skilled operator. At a signal, the automatically operated, water-cooled doors are opened. The charging machine lifts one of the pans,



Courtesy, American Rolling Mill Company

FIG. 2. Charging molten pig iron into the open-hearth furnace

shoots it forward through the door, revolves the pan so that its load is deposited on the hearth, and immediately withdraws Time and again this is repeated. Each of these pans has been carefully weighed in the stockyard, the quantity of each material charged depending upon the grade of iron or steel to be made.

In modern practice, the pig iron is charged into the open hearth in liquid form When the blast furnace is tapped, the molten pig iron is taken directly to the open-hearth building and stored in a huge, brick-

lined vessel, called a "mixer." This acts as a container, keeps the pig iron liquid, and, by receiving pig of different casts, makes for greater uniformity. A huge ladleful of this hot pig iron is taken from the mixer and poured directly into the furnace. In plants which do not possess blast furnaces, pig iron is sometimes transported many miles in specially built cars. One of the first to inaugurate this practice was the Middletown, Ohio, plant of The American Rolling Mill Company. A blast furnace located some 12 miles away made the pig iron. Special "land-submarine" cars, each weighing 350 tons when loaded, were designed to keep the pig iron molten during transportation, and the railroad had to be entirely rebuilt to carry this great weight.

Chemical analysis of metal samples. As the materials in the open-hearth furnace melt down, a glance through the furnace door reveals the liquid metal seething like a miniature volcano. That "boiling" action is exactly what the furnace operator desires, for to him it means that carbon monoxide is being given off through the combination of the oxygen from the ore and the carbon of the metal, and that the impurities are being destroyed. From time to time, he may add more iron ore to keep up this boiling action. At intervals, samples of the liquid metal are taken from the furnace and rushed to the laboratory. Pneumatic tubes, similar to those used in department stores, are sometimes used for the rapid transportation of these samples. Finally, the chemist's O.K. flashes back to the melter, and the furnace is ready to tap. Here is a typical analysis of an ingot iron and a steel heat:

	Ingot Iron	*Mild Steel*
Carbon	.015	.100
Manganese	.018	.400
Sulphur	.023	.030
Phosphorus	.004	.015
Silicon	.003	.005
Total	.063	.550

Tapping the furnace. Activities are now transferred for the time being to the back, or tapping side, of the furnace. Under the tap hole has been placed a clay-lined trough, through which the metal will flow into a great 150-ton brick-lined ladle, which is waiting in the pit below. The "pit" is the longitudinal half of the floor of the building. It is actually on the ground level. The other half, as has been explained, is given over to the checker chambers and the charging floor, the checker chambers being on the lower elevation and the hearth, or charging floor, directly above. Thus the charging floor is actually a sort of mezzanine.

To proceed with the tapping of the furnace, a workman digs away at the clay plug and then attacks it viciously with an oxy-acetylene burner. Around on the charging side, the melter and a crew of helpers are now ramming away at the "plug" with a long rod of iron. Finally, it gives way, and out plunges the imprisoned white-hot metal with a rush and a roar; it cascades into the waiting ladle, a miniature Niagara of fire and sparks As the "heat" is almost drained into the ladle, the metal seems

to froth and rise as if some kind of yeast had been cast into it. It trickles over the edge of the ladle, a beautiful sight. The overflow, however, is very desirable, for it is the slag removing itself.

Pouring the metal. High overhead, a giant crane crawls up to the ladle. It is equipped with trunions, which it lowers and which grasp the

Courtesy, American Rolling Mill Company

Fig 3. Amid great showers of sparks, molten metal pours from the huge ladle into ingot molds

huge lugs on the sides of the ladle. Triumphantly it carries its gigantic prize to the far side of the pit, where, on a long platform, stands the steel pourer. A long line of empty ingot molds have been drawn up alongside the platform, and the ladle is "spotted" directly over the first mold. The steel pourer, garbed in grotesque safety clothing, opens the nozzle on the bottom of the loader and fills a mold with this white, hot

metal. When it reaches the desired height, he quickly closes the nozzle, and the craneman moves the ladle to the next mold. Soon the train of hot metal goes merrily out of the building to stand for a short time in the ingot yard to solidify.

Capacity of open-hearth furnaces. Open-hearth furnaces vary in capacity from 10 tons to as high as 400 tons. The average furnace is probably of a 125-ton capacity, but the trend has recently been toward larger furnaces. Of course, the number of ingots obtainable from each heat also increases proportionately. The size of the ingot varies according to the purpose for which the metal is to be used.

The first pure iron by the open-hearth method. Prior to 1905, commercially pure iron had never been produced in an open-hearth furnace. Steel was the material usually manufactured. There had been so many complaints from farmers in the Middle West about the rapid rusting of wire fences, metal roofs, and agricultural machinery that the Department of Agriculture undertook a thorough and systematic investigation of the causes of rust. Examination of the antique irons which survived the ravages of rust revealed that the purer the metal, the greater was its resistance to rust. However, as no steelmaker had ever been successful in producing a pure iron, there were many difficulties involved. Because of the high temperatures at which the open hearth would have to be operated, steel men were afraid they would "burn up" their furnaces. Subsequent experiments have proved that, where the bath temperature of a heat of common steel was about 2,800 degrees F., the temperature of pure ingot iron was approximately 3,000 degrees F.

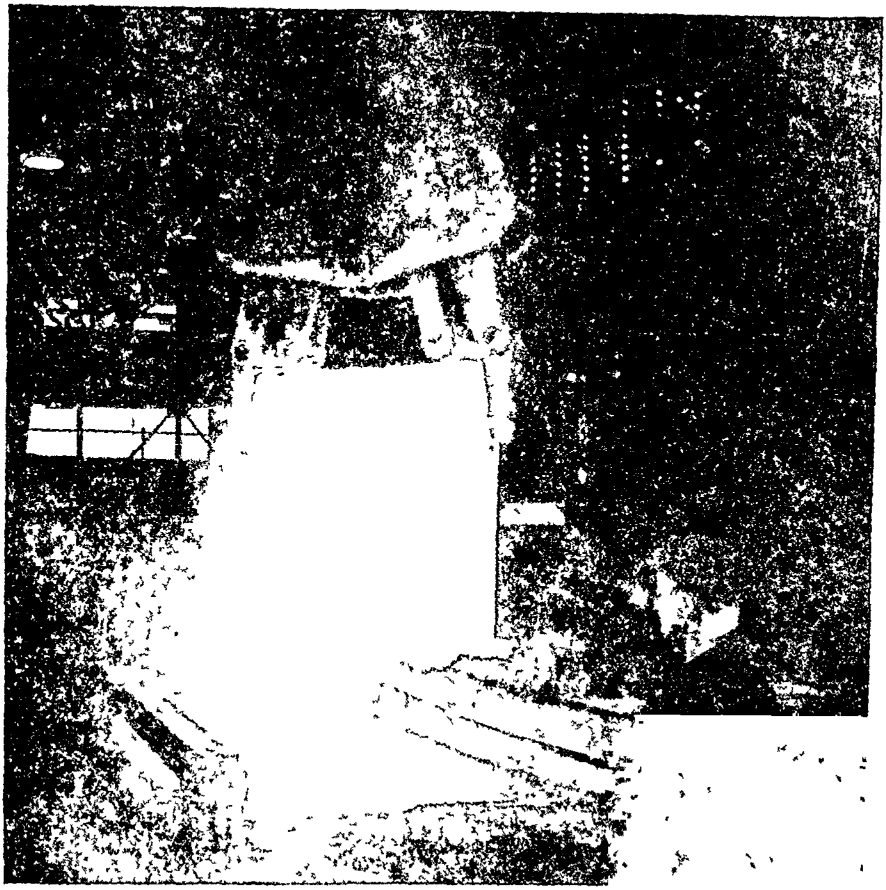
The American Rolling Mill Company, which at that time had but one little plant in Middletown, Ohio, decided to try the experiment. In 1906, they successfully produced the first heat of pure iron in an open-hearth furnace. Thus the open-hearth furnace was able to produce still another useful product for a world turning more and more to metal for the fulfillment of its wants.

The electric furnace. As the demand for alloy steel has increased, the electric furnace has been improved. As yet, this process can produce only a small quantity of steel in one heat. Its use is confined to the manufacture of high-priced alloys. Only 1½ per cent of today's steel is produced in electric furnaces.[1]

The soaking pits. By now the ingot which we left standing in the stripping yard has cooled sufficiently so that the mold can be removed. "Stripping" is done by means of an overhead crane which lifts the mold, leaving the ingot standing on a small car. Another crane now carries the ingot aloft to a series of furnaces called "soaking pits." These furnaces virtually sit on the surface of the ground. The doors

[1] In order to increase steelmaking capacity for defense and other purposes, the steel industry has constructed 21 new electric furnaces, all of which are expected to be in production early in 1941. The total capacity of the added electric furnaces is estimated at 900,000 net tons of steel ingots per year. This will increase by nearly 50 per cent the industry's electric-furnace capacity. American Iron and Steel Institute, *Steel Facts* (December, 1940).

through which the ingot is charged are located on the top, somewhat comparable to the freezing compartments of the local ice plant. These furnaces derive their name after the manner in which they perform their heating function. The ingots slowly soak up heat until they are uniformly heated throughout. The temperature at which soaking pits are



Courtesy, American Rolling Mill Company

Fig 4 Lifting an ingot from the soaking pit, where it has been "soaked" with heat prior to rolling.

usually operated is from 2,150 degrees to 2,300 degrees F. Coal-producer gas, natural gas, or a combination of either with fuel oil is the fuel used

Rolling the ingot. Most of the operations we have described have been of a metallurgical nature, but now the ingot is ready to undergo mechanical changes, such as being rolled into the shape desired The "blooming mill" is the initial rolling operation. It is a reversing mill, the ingot passing back and forth through the rolls. Mechanical handling apparatus lifts and turns the ingot in an almost human fashion. Power

is supplied either by huge reversing electric motors or by steam engines, often of 15,000 horsepower or even higher rating.

Making Sheet Steel

Methods of making sheet steel. Prior to 1750, sheets had been hammered from puddled iron. About the time of the Revolutionary War, Henry Cort, of England, devised a crude rolling mill. It employed the principle of a washing-machine wringer, except that there were grooves in the rolls, which reduced the balls of iron successively until the proper size was obtained.

From this point on in the manufacture of sheet metal, comparatively new inventions have revolutionized the industry. Perhaps it might be best, for purposes of comparison, to describe the method of manual rolling still in use by some companies.

Forming the bars. The blooming mill rolls the ingot down into a short thick slab called a "bloom." The ends of the bloom are then cropped off, for they contain small quantities of impurities. The cropped bloom then proceeds down the roll conveyor to the bar mill. Here it is rolled into long thin bars, weighing in general from 7 to 54 pounds per foot. Standard widths vary between 8 and 16 inches.

The mill clerk calculates how many sheet bars of each grade and size will be required to fill the rolling orders on the sheet mills during the coming week These calculations are passed to the Blooming Bar Mill Department, and the long bars are cut up into sheet bars to fill this order. Sheet bars are cut in lengths equal to the width of the sheets to be rolled.

The pickling process. After being transported in slings by an electric overhead crane to the sheet mill, these bars are "pickled" in a bath of dilute sulphuric acid to remove dirt and adhering scale. They are then reheated in a "pair" furnace and are ready for rolling in the sheet mill.

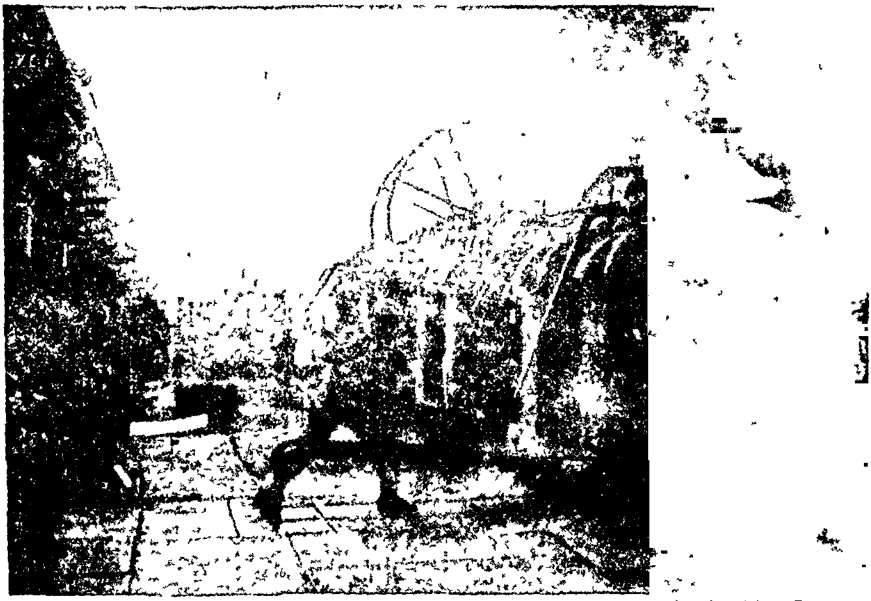
The manual-type sheet mill. This type of mill consists of two stands of two rolls each, one known as the "roughing stand" and the other as the "finishing stand." The pair heater drags two cherry-red bars from the heating furnace to the waiting rougher. He grasps first one with his tongs and then the other. Alternately, these are passed back and forth between the rolls until they have been reduced to the desired size. Curiously enough, the bars elongate in the direction of the rolling impact. Now, instead of a bar, say, 8 inches wide by 30 inches long, we have a rough sheet, 30 inches wide by possibly 48 inches long.

The pack process. The two partially finished sheets are next placed under a steam-driven doubling hammer and doubled together into what is known as a "pack." This, in turn, is placed in the heating furnace to absorb more heat before going through the finishing rolls.

When the pack has reached the desired temperature, which is largely determined by the visual examination of the heater, it is dragged back to the finishing stand. Back and forth between the rolls it goes again. The fact that two sheets are being rolled at a time does not mean that

they will be hopelessly forged together. The oxides, or tight scale, prevents that. When they have reached the desired length and are of the proper gauge, the finished pack is dragged away from the opposite side of the mill. The men with tongs pull the sheets apart. Usually they separate readily enough, although sometimes "stickers" are encountered.

Operation of the sheet mill. Sheet-mill, or "hot-mill," assemblies usually consist of eight mills to a "train," four on either side of the drive. Their bottom rolls are coupled together, and they are driven by reduction gears. Only the bottom roll is thus actuated, and each top roll is turned by friction of the lower roll on the metal passing between them.



Courtesy, American Rolling Mill Company

Fig. 5. A sheet mill of the manual type.

Sheet-mill roughing and finishing rolls usually range from 26 to 30 inches in diameter and from 36 to 48 inches long. Jobbing mills on which plates are rolled are considerably larger.

The necks of the lower rolls are journaled in permanent bearings in the housings or frames of the mill, while those of the upper rolls rest in sliding bearings mounted in guides. The latter are connected with individual crews, which terminate above the housings. The turning of a large wheel works the screw, which moves the roll and either increases or decreases the gap between the rolls, governing the gauge or thickness of the sheet being rolled

Disadvantage of the manual-type mill. A strong back is essential to the sheet-mill worker on the old manual-type mill. Moreover, he must be a skilled artisan, for each sheet is rolled according to specifica-

tions dictated by hand and eye. Of course, a high degree of uniformity cannot result, because the hand and the eye are not as reliable as the machine.

For generations, sheet metal has been rolled in just that way. There have been many refinements of Cort's method, but the basic principle has remained the same: men with tongs have pushed bars of steel back and forth between revolving rolls. Tradition records that it was the Saxons who first mastered the art; later the Welsh improved on it, though apparently their specialty was the rolling of tin plate. When the industry took root in the United States, many Welsh workmen emigrated from their native heath to the new land. As late as 1900, the highly specialized job of "turning" the rolls—grinding them down to the proper size and contour—was handled almost exclusively by Welsh workmen or their graduate apprentices in the trade.

The first continuous sheet mill. So it went until 1922, when The American Rolling Mill Company, after many years of experimenting, built its first continuous sheet mill at Ashland, Kentucky. Of this new method, John D. Knox wrote the following in *Steel:*

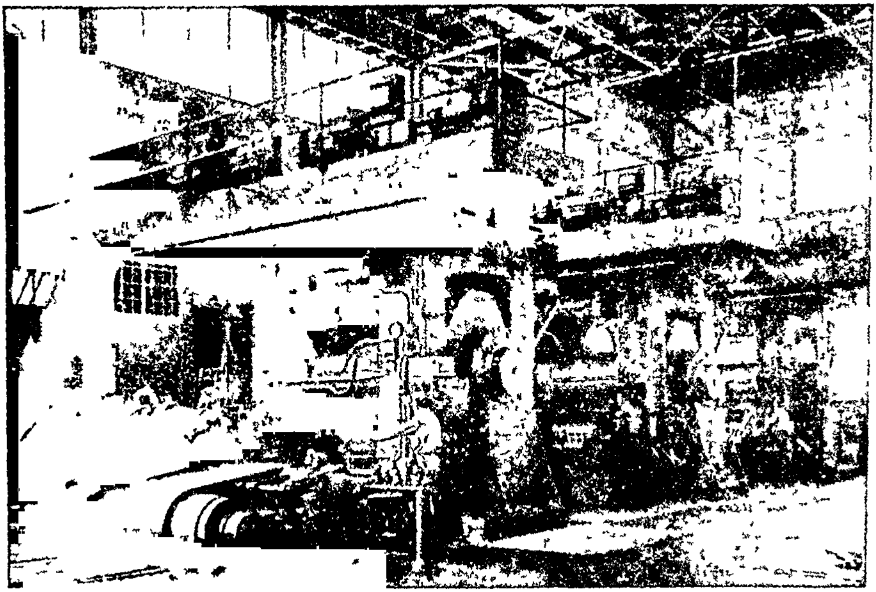
> Seldom has a new departure rendered better service to mankind than the continuous mill which permits ingots to be dispatched through stand after stand of rolls and to be transformed into 16-gage sheets and then to be reheated and again reduced to thinner gages, and all this actually accomplished mechanically. Roller tables take the place of tongs in the manipulation of steel into the rolls; automatically controlled furnaces take the place of sweating heaters. No heat-soaked floors to fatigue the mill crew, and the discerning eye perhaps will notice other things about the mill that signify the reign of a new order and emphasize that new values have taken the place of the old.

The preliminary experimental work had revealed that the task of designing and constructing the first continuous sheet mill was twofold. First, it was necessary to procure a better understanding of the characteristics of iron in its heated state when passing through the rolls than ever before. This involved prolonged and intricate studies of the changing conditions in a hot slab or bar as it passed from roll to furnace and from furnace to roll. Second, it was necessary to design special production and conveying machinery to break down the ingot into a wide thin sheet.

Operations of the continuous process. The radical difference between plants operating the manual-type sheet mill and those plants operating the continuous mills begins after the ingot leaves the soaking pits. From that point, sheets are rolled direct from the ingot. Ingots are generally rolled first into "blooms" on a rolling mill consisting of two or three power-driven steel rolls. If the mill has two rolls, it is called a "two-high" mill, while those with three rolls are known as "three-high." On a two-high mill both rolls may revolve both clockwise and counterclockwise, but they always move in opposite directions to each other, like a clothes wringer. They grip the metal and pull it between themselves, as the wringer does the laundry, reducing its thickness and lengthening it proportionally, and producing a long barlike bloom from a chunky ingot. By reversing the direction of the rolls, the steel is

pulled back and forth perhaps 20 times. After every round trip or two between the rolls, the metal is turned on its side so that all four sides are thoroughly kneaded. The man in charge, called the "roller," keeps the rolls adjusted so that the distance between their surfaces is always set to produce the desired thickness of the delivered slab.

Without reheating, the slabs are hot-sheared to desired lengths, and the rolling is continued to the finished strip, making the blooming or slabbing mill a part of the rolling line. This method has the advantage of conserving much heat and is in use successfully in a few mills rolling a limited number of products from a few grades of steel of one type.



Courtesy, American Rolling Mill Company

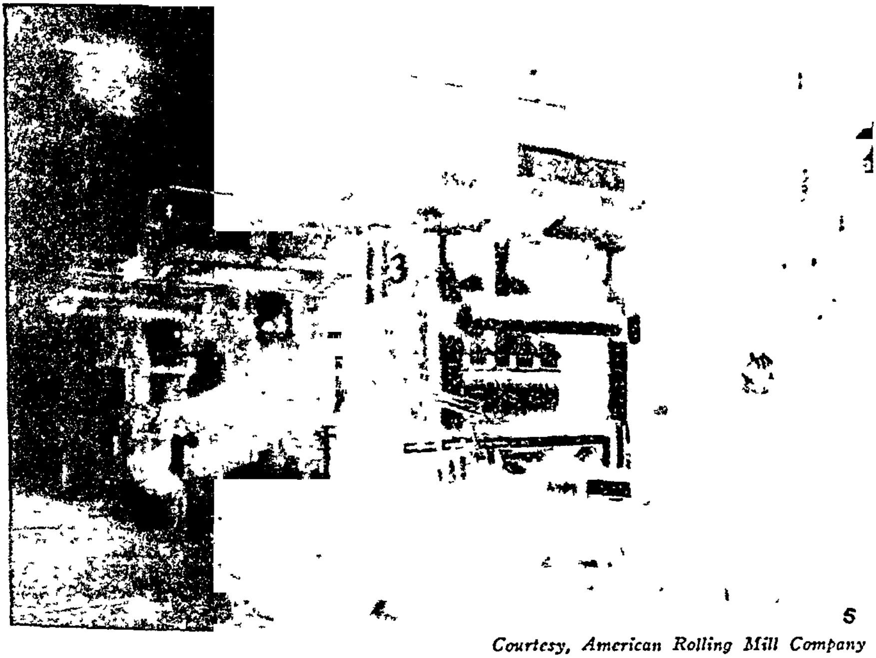
Fig 6 Cold-strip mill

In another and more popular method, the slabs are sheared hot, permitted to cool, inspected for surface defects, conditioned and assorted as found necessary, and then reheated and rolled to the product desired. While wasteful of heat, this method reduces the amount of finished product discarded, facilitates the rolling of small orders requiring different grades of steel, and permits early inspection and elimination of harmful defects. Other advantages become evident when the matter is viewed from a metallurgical standpoint, for the metallurgical problems involved in the production of sheets and strip include not only chemical composition of the steel but also furnace, mold, pouring, rolling, and conditioning practices—all of which affect the internal and surface characteristics of the product. The cold-slab practice also permits location of the strip mills at points removed from the blooming or slabbing mills, and in close

proximity to the sheet and tin mills, which consume a large part of their product.

The rolling operations are but one step in the business of producing sheets. Sheets in these modern times are being used for many different purposes, and it is the manufacturer's responsibility to provide a product which will meet the requirements of the buyer. To be able to do this will require many and varied treatments henceforth.

The annealing process. The rolling operations of the sheet mill have distorted the grain structure of each sheet. This must now be restored, and it is accomplished by annealing. Formerly, this was done by placing



Courtesy, American Rolling Mill Company

Fig. 7. Hot-strip mill.

stacks of sheets under huge cast-iron covers in large annealing furnaces, where they were permitted to stand for days exposed to a slow heat. The modern process provides for continuous annealing.

There are two methods of continuous annealing now in popular use. In one, the sheets are fastened end to end; but prior to entering the door of the continuous annealing furnace, the long strip passes high overhead over a revolving drum, and then down again and around another drum at the floor level. This throws a loop in the strip, which permits additional sheets to be added and allows for time variations in the operation of the sheet mill without checking the progress of the material into the furnace. The speed with which the long ribbon of metal passes through this roaring, gas-fired, pyrometer-controlled furnace usually depends

upon the grade and gauge being manufactured. A more recent method for continuous annealing has the sheets piled into a "lift" and placed into annealing boxes. These boxes then move through large annealing furnaces in much the same manner as a freight train passing through a tunnel. The tunnel represents the furnace and the cars representing the annealing boxes. As each box leaves the furnace, another is added to the charging end. The time in the furnace, the speed with which the boxes pass through, and the heat of the gas-fired furnace depend upon the grade and gauge being produced.

Removing the scale. Again the sheets must be "pickled" to insure a clean, scale-free surface. Great tanks of pickle liquor are next in line. On top of each tank is a round drum, and over this flows the long strip. It then goes down into the cleansing solution and up over the next drum, and so on.

Some of the long strips are rolled into coils. The coils are usually of a large enough diameter to avoid undue bending and cold working when the strip is uncoiled. The continuous pickling of coils is carried out in a continuous operation of several steps varying in different plants. In the more recently erected mills, equipment is provided for uncoiling the strip, shearing the ends to square them, stitching the ends of different coils together, conveying the strip through the pickling tanks, rinsing it with water to remove the ferrous sulphate solution that adheres to it, drying it, shearing out the stitching, and recoiling it.

Cold rolling and re-annealing. From this point on, the customer's requirements determine what succeeding treatments are necessary. Some uses for sheet metal require that it be cold-rolled and re-annealed. "Cold rolling" is just what the name implies: the cold sheets are passed through revolving rolls. Re-annealing is usually necessary to remove the strains and stresses imparted by cold rolling and to give the sheets a soft texture.

For certain finishes the sheets must have a bright, or deoxidized, surface. This is accomplished by controlling the atmosphere within the annealing box during its trip through the furnace. Perhaps the sheets may have to be cold-rolled again. Not only is the surface improved by cold rolling, but the elastic limit, tensile strength, yield point, and other physical properties are also improved.

Testing physical properties of the sheets. A field laboratory near these various sheet-finishing departments is equipped with modern testing instruments and a staff of trained metallurgists, who maintain a constant check on the various physical properties of the sheets in process

Flattening the sheets and protecting the surfaces. Some sheets must be very flat. This is accomplished either by "roller leveling," or passing them through a series of small rolls, or by "stretcher leveling," which is done by clamping both ends of a sheet in a machine which pulls it taut. Still other sheets must be coated with oil, to prevent marring of the surface or rusting in transit. The sheets are then sheared to the exact size desired.

Final inspection of sheets. The final operation before the sheets are loaded into the car is inspection. Under specially designed lamps,

trained inspectors scan each sheet for possible defects which have escaped the eyes of the operators. Samples are taken from time to time and tested by the metallurgists in the field laboratory.

American Rolling Mill Company's Contribution to the Steel Industry

Of the ARMCO continuous sheet mill, *The Iron Age* states:

> In referring to the description of the much talked of but little known Ashland plant of The American Rolling Mill Company, the impulse is to write in praise of such a notable departure in sheet rolling and to enlarge on its economic importance. What checks such expression is a fear of overstating the case, so epochal seems this and other contributions now being made to the rapid rolling of thin, wide steel sheets and strips.

What will the continuous process mean to a world ever finding new uses for sheet metal? Continuous units are producing vastly more than the old manual-type mills and are making available sheet metal of better quality and at lower costs than prior generations ever dreamed of.

Following the great success of ARMCO's continuous mill in Ashland, other large steel companies installed the process. Today, 27 of these big continuous mills have been constructed in the United States, and their total cost has amounted to $550,000,000.

In addition to installing continuous mills in their plants at Middletown, Ohio, and Butler, Pennsylvania, The American Rolling Mill Company has granted licenses to the other leaders in industry. These companies include the United States Steel Corporation, Youngstown Sheet and Tube Company, the Inland Steel Company, Otis Steel Company, Gulf States Steel Corporation, Wheeling Steeling Corporation, Great Lakes Steel Company, Weirton Steel Company, the Republic Steel Corporation, Allegheny Ludlum Steel Company, Bethlehem Steel Corporation, Granite City Steel Company, and Jones and Laughlin Steel Corporation.

Steel Production of the United States

As world consumption for iron and steel products has increased, the productive capacity of the steel plants has kept pace with it. Indeed, certain economists insist there is a perpetual state of overproduction in the industry and point out that the industry is "either rich or in rags." However, the industry must be ready to meet great production demands on short notice when emergencies arise, such as the immense armament program begun in the fall of 1940. Since the First World War, which brought out many applications for iron and steel, the productive capacity of the country has grown by leaps and bounds. Production reached its peak in 1937, when the flat-rolled, lightweight products alone reached

the staggering total of 21,834,272 net tons. The amount can be classified as follows:

Product	*Net Tonnage*
Sheets and plates[a]	15,721,272
Tin plate[b]	2,869,963
Strips[c]	3,243,028

[a] A product 3/16 of an inch or more in thickness.
[b] Tin plate is the product of a tin mill. Gauges are usually very light, ranging from 38 gauge to 15 gauge. Limited to 14 square feet on surface area (Extreme width is 32 inches; extreme length, 84 inches)
[c] Limited in width to 12 inches maximum in 1939.

To this sum should be added the tonnage of the heavier items—such as structural steel, rails, bar shapes, and other miscellaneous items—which brings the gross production for the peak year, 1937, up to 41,178,356 gross tons. This amount does not include the tonnage of forged iron, wrought iron, cast iron, and other miscellaneous iron and steel products. Production in 1940 is expected to exceed that in 1937.[2]

Important allied industries. This chapter would not be complete without some reference to two allied industries upon whose development the sheet-iron and steel industry has depended to a large extent for the more recent increased consumption of steel-mill products. The great strides made by the welding industry has made possible new uses for all classes of iron and steel products, from the heaviest structural members to the lightest sheets. Perhaps we are all more intimately familiar with what the porcelain-enameling industry has done. In every home we see gleaming examples of porcelain enamel fused on iron and steel sheets. Stainless steel, too, must be considered, as in recent years its applications have multiplied many times. Though the tonnage of stainless steel is relatively small, it plays an important role in our everyday life.

Everywhere we go, we see iron and steel at work in the service of mankind. Our ocean liners, great locomotives, steel-skeleton skyscrapers, automobiles, and great bridges are all monuments to the industry. Then there are the thousands of smaller applications—such as culverts to drain our roadways, iron caskets and grave vaults, radio, great electrical machinery, kitchen ranges, stainless-steel cutlery and tableware, dairy equipment, tables, tanks, ventilating systems, furnaces, tubs, barrels, electric refrigerators, roofs, gutters, downspouts, and countless other products to utilize the output of our great steel mills.

Disposition of rolled iron and steel products. There may be some question in the reader's mind as to just where this vast output is used. According to *The Iron Age*, the 1939 distribution of rolled-iron and steel products consumed in the various industries was as follows: machinery, 3.7 per cent; containers, 8.5 per cent; agriculture, 2.5 per cent; export,

[2] Added new facilities for production of steel for defense and other purposes include new electric furnaces to produce 900,000 net tons of steel ingots per year and 1,300,000 tons of additional capacity for producing open-hearth steel. American Iron and Steel Institute, *Steel Facts* (December, 1940).

6.4 per cent; oil, gas, water, and mining, 5.3 per cent; building and construction, 14.6 per cent; railroads, 9.5 per cent; automotive, 16.7 per cent; and all others, 31 3 per cent.

Important by-products of the steel industry. A branch of the iron and steel industry productive of many valuable by-products is that of the coke ovens of the blast furnace. When the blast furnace turned from charcoal to coke as a fuel, it tapped a rich and unsuspected by-product mine. At the close of 1939, according to a survey by the American Iron and Steel Institute, there were only four charcoal furnaces in the United States. There is a common saying that the by-products of the coke ovens are worth as much as the coke the furnace produces. This statement is debatable, but the by-products do constitute a rich source of revenue. Coal gas is one of the chief by-products. This is washed, stored, and sold to industries and municipalities. Other valuable products are tar, ammonia, and ammonium sulphate, which is a fertilizer high in nitrogen. Even the slag from the furnace is granulated and sold as an aggregate for concrete and road building. The remainder of the industry is not so fortunate. Its chief source of by-product revenue is derived from salvaged or degraded material.

Marketing Steel Products

Perhaps in no other line of endeavor are the marketing activities so ramified. This can easily be accounted for, since iron and steel are basic products and are not sold directly to the ultimate consumer. Particularly is this true of the high-grade sheet section, where a knowledge of operating conditions in customer industries is absolutely essential.

Salesmen and research workers must not only be specialists in the operations in customers' plants but must also be thoroughly familiar with the manufacture of iron and steel, because sheets are usually sold with a guarantee to stand the drawing or forming operations with a definite, specified breakage tolerance. This situation naturally requires technical experience on the part of the salesman, and it has resulted in attracting many engineers to the distribution end of the business.

Domestic sales organization. Sales activities are usually organized by establishing district offices in convenient locations over the country. These offices are presided over by district managers, whose salesmen keep in constant contact with the buyers and familiarize themselves with the changing conditions in that particular market. A home sales department is maintained in the general office for the purpose of expediting orders, passing on information to district offices, advertising the product, and making special contacts with customers. The activities of subdepartments are usually devoted specifically to promoting the sale of some particular grade of material. The actual selling activities are under the supervision of a general sales manager, while a vice president in charge of distribution coördinates all sales, advertising, and promotional efforts.

Export practices. In export work, the trade customs conform to those established in the country in which the buyer is a resident. Some of

the larger companies have export offices all over the world; at one time the export business was handled by shipping agents in New York. Later, separate export corporations were organized by several of the leading concerns.

Manufacturing Rails, Structural Steel, Bars, Wire, and Pipes

Rails. Railroads consume approximately 9½ per cent of the entire steel output of the United States, steel rails making the major portion of this figure.

A description of the open-hearth furnace operations was given in previous paragraphs. Up to that point the manufacture of rails resembles that of sheet steel. The molten steel is poured into the molds. After cooling, the ingots are stripped of the molds and conveyed to the soaking pits, where they remain for approximately 1½ hours, the exact time depending upon the particular kind of steel. When the ingots have soaked up sufficient heat to be set and are of uniform heat throughout, the operator of the soaking pit raises the temperature very carefully until the ingot reaches the correct temperature for rolling. A crane now reaches down, lifts out the ingot, and places it on the mill table, ready to enter between two great revolving rolls, which are 3 feet in diameter and 10 feet long. The steel ingot, aided by the revolving rolls of the mill table, passes through these water-cooled rolls, its movements controlled by a set of levers operated from a platform so located that the operator has an unobstructed view of the ingot and the mill table. Its movements still controlled by levers, the ingot is mechanically turned over, the mill is reversed, the ingot comes back, and is again drawn through the rolls. Several times the ingot is passed to and fro through the mill; with each successive operation, it grows thinner and thinner and greatly increases in length. When the ingot has been rolled until it is but a quarter of its original thickness, it is passed down a runway and over conveying rolls to the blooming shears, which cut off the rough ends and cut the bar in two.

These pieces then pass on to the first roughing rolls. As the piece of steel emerges from the rolls, it shows, for the first time, a resemblance to the rail it will eventually become. The steel passes three times through these first roughing rolls, then once through a second set of roughing rolls, and once through dummy rolls; it is then ready for the finishing rolls. After it is passed four times through the finishing rolls, the long rail emerges and is cut into proper lengths by circular saws. The rails are then cooled and straightened, ready to be loaded into cars and shipped.

Structural steel. Approximately 8½ per cent of the steel output of the United States is consumed in structural steel. This type of steel is made in practically the same manner as rails. The structural steel is shaped into I-beams, channels, and angles in rolls specially designed for the purpose. This steel is shipped to the various fabricating plants, where it is converted into numerous commodities. It is used for building

construction, subways, bridges, ships, and for many other important purposes.

Bar steel and wire. In a similar manner ingots are rolled to the desired dimensions and cut into billets. These billets are then re-heated and rolled into rods through a series of mills. Rods may be further converted into wire or wire products by what is known as the "cold-drawn process." This is accomplished by drawing the rod through a series of steel dies with holes of various sizes until it has been reduced to the desired diameter. It is then heat-treated to give it the physical characteristics desired in the product for which it eventually will be used. These products vary from wire fencing, steel cables, and springs to fine wire nails and high-grade music wire.

Pipes and tubes. Billets are shipped in carload lots to the pipe manufacturing plants, where they are heated in furnaces and then rolled flat to the exact width and thickness desired, depending upon the pipe which will be made of them. This strip of metal is known as "skelp."

Pipes and tubes are of two general classifications, commonly known as "welded" and "seamless." The welded pipe is manufactured by two processes, butt weld and lap weld. Pipes from 1/8 of an inch to 3 inches in diameter are usually produced by the butt-weld process, which consists of drawing a heated skelp through a bell-shaped die, known as a "welding bell," which brings the edges of the skelp together and unites or welds them by the pressure of the die.

Pipe sizes from 1¼ inches to 30 inches in diameter are manufactured by the lap-weld process, which is accomplished by passing the cherry-red hot skelp through either a set of three rolls or a die. In this process, a rough tube is formed with one of the edges overlapping the other. It is then heated to a welding heat and passed through two half-round rolls, which together are the exact size of the outside diameter of the pipe. In the inside of the pipe is placed a steel sphere, which, in diameter, is exactly the size of the inside dimension of the pipe. As the rolls pass over the hot lap with the sphere inside the pipe, the action of the rolls on the lap over the sphere is similar to that of a sledge striking a piece of steel on an anvil, and the edges of the pipe are welded together. Finally, these pipes are sized, straightened, and tested, after which they are ready for shipment to consumers.

Seamless tubes are made by one of two processes commonly known as the "cupping method" and the "piercing method." The cupping process consists of cutting a hot steel plate in a circular or disc form and placing it in a gas- or oil-heated furnace until it reaches the required temperature. It is then placed in a hydraulic press, formed into the shape of a cup, and finally elongated to the proper dimensions. The piercing process consists of forcing a hot cylindrical billet over a pointed mandrel and rolling it to the desired dimensions. The rough ends of all pipes are trimmed off, and in some cases the pipe is threaded and a coupling screwed on one end.

For all ordinary purposes butt-weld pipe is used, but in cases where

the internal pressure is high, as in hydraulic lines, high-pressure steam lines, gas lines, and oil lines lap-welded pipe is utilized.

The Financial Structure

The financial history of the iron and steel industry is much like that of any other industry. In the early days, companies were privately owned. Later, when it was necessary to secure additional outside capital, bonds and preferred stock were issued. It was not possible to secure capital without some preferential guarantee, because of the hazards of the industry. When the modern corporation came into existence and efficient methods of distribution and manufacturing were developed, common stock was offered to investors.

Personnel

The industry employs men of all trades and professions, from the ditch digger in the plant to the international banker who is on the board of directors. It is the bread and butter of 655,536 people in this country, according to figures compiled in 1939 by the American Iron and Steel Institute. This does not include the thousands employed in the foundries, refractory plants, scrap yards, coal mines, and other industries affiliated as sources of supply. Competition and the necessity for reduced manufacturing costs led the industry many years ago to adopt coöperative and humane policies in dealing with personnel. Safety and training are stressed to the fullest degree. Group life insurance and mutual benefits for the sick are provided by most companies. Some concerns provide the workers with free medical service. Employees are encouraged to improve their technical and job knowledge, and many companies reward the diligent with better jobs The 8-hour day has been in effect for a long time.

Health conditions. Steel has ever provided a romantic background for fiction, and many false impressions have been formed For example, it was commonly supposed in years gone by that any one who worked in a steel plant was bound to die an early death, either by accident or because of broken health. The steel industry has shown that this was an illusion. Fewer accidents occur in the average steel plant than on the city or village streets, and occupational diseases are rare. It is true that, in the old days, much physical effort was required of the worker, and strains and hernias were quite common. However, labor-saving machinery has reduced this danger to a great extent. The steelworker's chief health hazard today is the heat. Too rapid a change from the heat of the furnace to the raw outside air is sometimes the cause of the common cold and its complications, but this disease is found in all industries. In certain branches of the industry—foundries, for instance—silicosis may be contracted from silica dust taken into the workmen's lungs from the air. Most companies today carefully and periodically check all men who are exposed and provide other safeguards against silicosis.

Statistics of the Steel Industry

According to the American Iron and Steel Institute, the bulk of the steelmaking capacity of the United States is concentrated in the hands of but nine companies. Without regard to the class of products manufactured, these leading companies and their respective ingot capacities for 1938 are given as follows:

Company	*Net Tonnage*
United States Steel Corporation	28,885,000
Bethlehem Steel Company	11,280,000
Republic Steel Corporation	7,280,000
Jones and Laughlin Steel Corporation	4,112,000
National Steel Corporation	3,808,000
Youngstown Sheet and Tube Company	3,491,000
Inland Steel Company	3,091,000
The American Rolling Mill Company	2,915,000
Wheeling Steel Corporation	1,960,000

Figures obtained from the same source show that the ingot capacity of the United States was increased by 19,306,000 net tons during the period from 1920 to 1940.

The Future of the Steel Industry

What is ahead for the iron and steel industry? Can it continue to grow? No one knows the answer, but history reveals that it has always progressed. New outlets for metal must be found; indeed, many developments are under way at this very moment. It does not seem unlikely that some not far distant day our dwelling houses will be of iron and steel. Many such houses are already standing in this country, proving their practicability. Skyscrapers clothed in Jacob's coat of many colors, of porcelain enamel on iron, may line the horizon. Highways on an iron base may some day line the countryside. Iron and steel may be used in conjunction with the new plastics industry, which is so rapidly growing. More and more of our furniture may be made of iron and steel. Cribbing made of iron sheets has already been developed to protect banks from stream encroachment. Spiral-welded pipe is now being used for water, stem, gas, and air; gas, for instance, travels from Texas to Chicago through this pipe made from sheets. And so it goes. The engineer and the research man are working shoulder to shoulder creating new markets, broadening old. In their hands lies the future of the industry.

18

The Copper Industry

From the dawn of civilization on, through medieval and modern times, copper has been the world's most versatile metal. Copper or one of its alloys has a part in almost every phase of our industrial and everyday life. We do not have to look very far before we encounter something of vital importance in our work or comfort in which copper, in one form or another, is in service.

The electrical current which lights our rooms is generated by equipment in which copper has a vital part, and it is carried to us on copper wires. Our telephone lines and cables are copper. If the house in which we live is well constructed it may have a copper roof; at least, it will have copper gutters, flashings, and downspouts. Our transportation systems would be far less efficient without the use of copper and brass, brass being an alloy of copper and zinc. Brass and copper pipe and tube carry water into our homes and enable it to be circulated rust-free for our convenience. Our modern mechanical refrigeration and various forms of heating systems, including radiators, make effective use of this metal. Copper or one of its alloys is used in the construction of locks that keep us secure against intruders at night. Bronze, which is the alloy of copper and tin, is used to ornament the important buildings that hold our art treasures or from which are conducted the affairs of the Government.

Since the earliest recollection of man, copper, brass, and bronze have had a part in our scheme of life; but it has been only within recent years that their field has been broadened to embrace almost every phase of our existence. New developments are under way in this ever-progressive industry that will further extend the field. Additional uses of copper will come through the discovery of new copper alloys and the perfection of further applications, particularly in the sphere of building construction.

In a sense, copper has had a part as great as, if not greater than, any other commodity in determining the status of our present independence and well-being. It has determined the outcome of wars. It has been said that the nation that goes to war without an adequate supply of copper, for use in munitions and the maintenance of quick communica-

tion, is as badly off as a nation without a competent general staff. The collapse of the Central Powers in the First World War was probably due as much to their shortage of copper as to any other one factor.

Early History of Copper

Copper is the world's oldest metal. Archaeological research has led us to believe that it was used by primitive people at least 8,000 years ago. Perhaps it was known some thousands of years before that time. Much of the early history of the human race has been divulged to us by copper relics that have come down through centuries.

The Bronze Age was a distinct era in history, succeeding the more primitive Stone Age. Archaeologists and metallurgists are not in agreement in their theories as to how the people of the Bronze Age developed this alloy of copper and tin, but it is possible that it was discovered by accident in some primitive smelting process.

At any rate, there is evidence that copper metals were used in ancient times in Europe, Asia, and the two Americas. Perhaps it was in Mesopotamia or in Egypt that man first became acquainted with the metal and used it. Relics have been found indicating that the Egyptian king, Seneferu, worked some copper mines about 3700 B.C., but obviously that was a late period in the use of the metal.

Copper was in service in North America before the discovery of America by Columbus. Various articles of copper manufacture have been discovered in the works of the mound builders. The chief source of supply was the vast Lake Superior deposits, stories of which came to the whites soon after the settlement of the American colonies. Many years later these deposits became the center of extensive commercial developments.

Copper Developments of the Nineteenth Century

From about 1844, which date saw the real beginning of America's copper industry, the Lake Superior region gave us most of our copper, with Michigan leading as a copper-producing state.

In 1864, a small pit left open by some forgotten miner was discovered in Montana; and, presently, through the initiative of Marcus Daly, this section was developed into the now famous mines of the Anaconda Company. A contemporary pioneer in this enterprise was the late Senator W. A. Clark. It was not until 1875 that any very systematic development of copper mines took place here, although there had been a small production before that date. In 1880 came a marked increase of production, amounting to a total of 1,000,000 pounds in the year; but active copper mining did not really begin until 1882, when the yield was 9,000,000 pounds. The first railroad connection with the rest of the world had been completed in the preceding December. Since then the relative importance of copper, silver, and gold has been exactly the reverse of what it was in the pioneer days of the state. The yearly output from the

mines of the Butte district now amounts to hundreds of millions of pounds of copper. Silver and gold are produced as by-products.

It is interesting and significant that the year 1880, which marked the beginning of Montana's important copper output, saw also the beginning of progress in the use of electricity and the development of electrical industries, with their need for large supplies of copper. While the copper industry has made possible the marvelous electrical developments of the present day, it has in turn greatly benefited by the use of electric-power machinery and the electrolytic method of refining. It is of special local interest that the ore is brought from Butte to Anaconda on a railroad that has been electrified since 1912-1913 and has the distinction of being the first railroad in the world to attempt high-voltage (2,400 volts), direct-current operation.

It was in the seventies and eighties of the nineteenth century that the American copper industry became firmly entrenched and was on its way to world leadership The development of copper mining in Arizona began about 10 years later, and this state has for many years been the principal copper producer. Utah now ranks second; Montana, third.

One of the romances of the industry was the perfection of a process at the beginning of the present century by which copper could be extracted profitably from the so-called "porphyry ores." These ores are of low grade, sometimes containing 1 per cent or less of copper. They are among the important sources of the metal today. A huge mountain of porphyry ore exists in Utah and is worked as an open-cut or surface mine It yields most of the copper produced in Utah, which ranks second among the copper states. This development was due largely to the work of D C. Jackling, president of the Utah Copper Company, and to R. C. Gemmel. There are also large porphyry copper deposits now worked in Arizona, Nevada, and New Mexico.

The World's Copper-Producing Areas

America's contribution to world production. America leads the rest of the world in the production of copper. Figures for 1929, the peak year in American copper production, show that the copper mines of the world produced 2,118,209 short tons, of which, in general divisions, 1,249,-998 came from North America, 416,901 from South America, 167,474 from Europe, 172,561 from Africa, and 91,989 from Asia Of the North American output, that of the United States amounted to 1,026,348 tons, or approximately half of the world's total production. In South America, Chile produced 349,221 tons.

From the most recent figures available, those for 1939-1940, it is found that, whereas the total annual production of copper for the world increased somewhat over that given above for 1929, the production from the United States alone has dropped from about one half to approximately one third of the world's total.

Africa's contribution to world production. Africa is an important factor in copper production through the development of large deposits

in the Katanga region of the Belgian Congo and, more especially, in Northern Rhodesia, which now produces from two to three times as much as the Congo.

World's largest copper deposit. The largest copper deposit in the world is in Chile, and it is owned by Americans. Chile supplied the bulk of the world's copper in the period prior to the development of the North American industry and today ranks second only to the United States in output. Canada has become an important producer since 1930. Mexico and Peru are other American countries that produce copper.

Spain has a famous copper mine, Rio Tinto, which was worked by the Phoenicians before 1200 B.C. It is still producing some copper, but Serbia now leads the European countries in output.

Important American copper interests. In the United States, the three chief producers are the Kennecott Copper Corporation, Anaconda Copper Mining Company, and Phelps Dodge Corporation. Each of these groups operates several mining properties, either directly or through subsidiary corporations.

Copper Mining

The methods employed in copper mining vary widely in accordance with conditions under which the ore is found and with its character. In surface mining, the ore is first broken by blasting and then loaded by large mechanical shovels, usually electrically driven, into railroad dump cars for transport to concentrator or smelter. In underground mines, shafts are sunk to reach the ore body. From these, horizontal openings known as "drifts" and "crosscuts" are driven in the ore body and connected at intervals with vertical openings (raises), thus dividing the ore body into blocks. There are many different methods of mining such blocks. Some underground work extends to great depths—over a mile—and there may be several hundred miles of lateral workings in a given mine.

Open-pit mines. To the uninitiated, the surface mine is the more spectacular, for there it is possible to behold activities of the enterprise. The rapid operation of the electric shovels, dumping the ore into cars, keeps pace with the shifting of ore-laden trains over tracks that lead directly to the mills and smelters. These surface workings are busy hives of industry with their network of rails, which are constantly shifted to enable the shovels to get at the ore Not too far off from the work there may be offices, workshops for repairs, and many other buildings, including houses and places of entertainment for the employees and schools for their children.

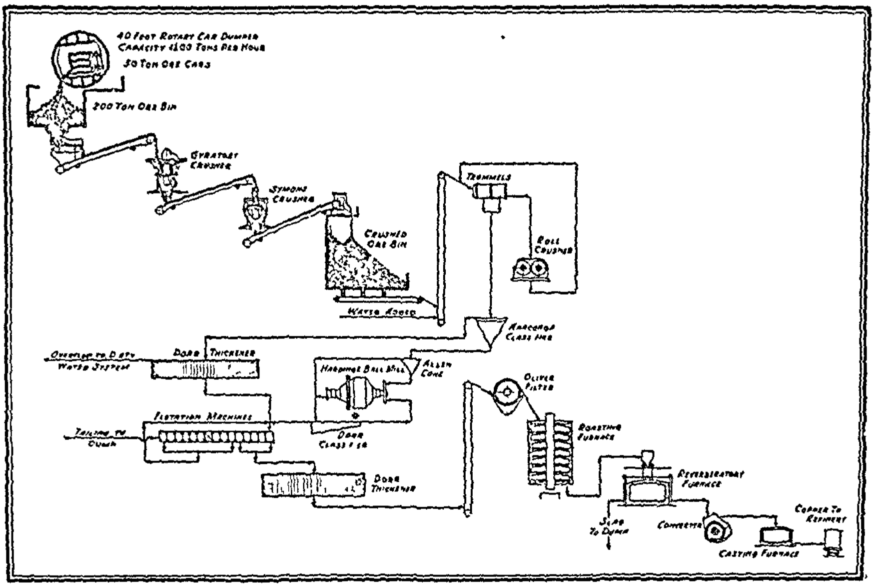
Underground mines. All of these features likewise exist in underground operations, although they are not really seen by the visitor at the mine Far below the surface are underground railroads, where electric locomotives haul the empty ore cars to the chambers or stopes where miners are at work. Ventilating and pumping machinery, to make the mines livable and free from water, are in operation wherever needed.

The ore is loaded into cars and hauled to the shaft; is dumped into skips, which may hold several tons; and is hoisted to the surface, sometimes at the rate of almost a mile a minute.

Concentrating and Smelting Copper Ore

There are three general methods of obtaining copper from ore.

The first method is common in the Lake Superior region, where the copper in the ores occurs as "native" copper—*i.e.*, metal. The ore is crushed to suitable size and then sent to a concentrating mill. There jigs, ore-dressing tables, or flotation machines separate the copper from



Reproduced by courtesy of Anaconda Copper Mining Co

Fig. 1. The copper-ore process

the waste. The copper concentrate is then turned over to the smelter to be melted in reverberatory furnaces. Air is blown through the molten mass for the purpose of oxidizing impurities that are slagged off. The molten copper is then subjected to a reducing action and, finally, when brought to the proper pitch, is cast into commercial shapes known as "ingots," "cakes," "billets," and "wire bars."

A second method of treating copper ores is by "leaching." This is used most frequently for oxidized copper ores. The ore is crushed and placed in large vats, sometimes having a capacity of more than 10,000 tons. Leaching solutions, which are acidified with sulphuric acid, are allowed to percolate through the ore; the acid leaches out the copper in the form of a copper-sulphate solution, which in turn passes to the electrolytic tank house, leaving behind the waste or "tailings." In the tanks in the

tank house, an electric current flows from insoluble anodes through this copper solution and deposits metallic copper on cathodes. These cathodes, after being sufficiently built up with copper, eventually go to reverberatory furnaces for melting and casting into commercial shapes.

The third method is used for treating ores in which the copper occurs principally as copper or copper-iron sulphides. These ores are crushed and concentrated usually by the "flotation process." The concentrates may be smelted "raw" in a reverberatory furnace or may first be sent to a roasting furnace for the twofold purpose of eliminating some of the sulphur and effecting oxidation of impurities. After the addition of proper fluxes, the charge is melted in reverberatory furnaces to a liquid state; the floating slag is removed through a taphole at one side of the furnace; and the "matte," which is a copper-iron sulphide containing such gold, silver, and platinum as may have been present in the ore, collects in the bottom of the furnace and is tapped periodically into ladles. In its molten state, the matte is dumped into converters, where it is "Bessemerized." In this process, air is blown through the molten mass and, contrary to what might be expected, the mass is not cooled but heated, owing to the oxidation of the sulphur and iron content. Two products result: copper and a slag composed principally of silica iron, and alumina, along with a small portion of copper that is later reclaimed. Copper produced by this method is known as "blister copper," because, when cast, the entrained gases bubble out and form blisters on the surface of the pigs. Blister copper, usually contains about 98 per cent copper. Ordinarily, it is subjected to a further fire-refining process and then cast into anode form.

Refining of Copper

Anodes are suspended in tanks filled with an acidified copper solution; electric current is passed through the anode, which causes copper to be taken into solution and deposited at the cathode as pure copper, the impurities and precious metals dropping as a slime to the bottom of the tank for further treating or being dissolved in the solution, which therefore requires purification before re-use. The electrolytic cathodes are removed from the tanks periodically, melted in reverberatory furnaces, and cast into commercial shapes.

The commercial shapes of refined copper. Commercial shapes of copper are of the form, dimensions, and weight best suited to the purpose for which the copper is to be used. Refined copper is used in many industries, such as the manufacture of brass and other alloys, copper-rolling mills, wire-drawing mills, tube mills, and so forth, and each industry has designed and specified for its own particular use special shapes of refined copper best suited for its purpose.

Ingots. Copper ingots are used primarily where the copper has to be remelted in crucibles either for the making of copper castings or for the manufacture of alloys such as brass, bronze, nickel-silver, and so on. Ingots, therefore, are of a shape that will readily fit into crucibles; they

are about 10 inches long and weigh approximately 20 pounds. They are made with a notch in them to facilitate breaking when necessary. Being small, ingots are difficult to handle and ship in large quantities, and ingot bars are often used instead. An ingot bar may be considered as two or more ingots in one bar, which, owing to the deep notches, are readily broken apart.

Wire bars. Wire bars, the most popular form of refined copper, are used by wire mills for the drawing of copper wire. These bars are generally cast with pointed ends in order to facilitate the bar entering the first set of rolls. The size and weight of wire bars vary, but their dimensions and weights are being standardized. The 225-pound bar and 265-pound bar, both of which are 54 inches long, are the sizes most commonly used.

Slabs and cakes. Slabs and cakes of various sizes are used for rolling purposes, where sheet copper, strips, bus bars, and so forth are the final products. The sizes of these vary greatly, depending on the sizes and weights of the finished product required. Circular cakes are used for the manufacture of large, seamless, cylindrical products such as kettles, tanks and other vessels.

Billets. Billets are used for the manufacture of seamless copper tubes of all sizes. Billets vary from 2 to 6 inches in diameter, and go up to 52 inches in length and 1,600 pounds in weight.

Precious metals. The functions of a copper refinery are twofold: (1) to produce high-grade copper metal; and (2) to recover from the blister copper the precious metals that it contains. It is estimated that about 80 per cent of the total silver production and 15 per cent of the total gold production of the world are recovered as by-products from copper, lead, nickel, and cobalt refining.

In the electrolytic refining of copper, all the precious metals originally in the anodes drop to the bottom of the tanks during the process of electrolysis and are known as "slimes," or "anode mud." When the scrap anodes are lifted from the tanks, after approximately 30 days of electrolysis, the slime is swept from the bottom of the tank and pumped to the silver refinery. The slime will vary considerably in composition, depending upon the grade of blister copper refined. A typical slime will have about the following composition:

Metal	*Per Cent*	*Ounces Per Ton*
Silver	43.23	12,610
Gold	234	68.4
Copper	13 86	
Arsenic	3 88	
Antimony	2 46	
Selenium	1 46	
Tellurium	6.14	
Lead	3.96	
Bismuth	0.26	
Iron	0 22	
Nickel	0 27	

Methods of Fabrication

The product of the refineries goes to the fabricating mills in the commercial shape best suited for the special purpose of manufacture. Copper cakes go to rolling or sheet mills, billets to tube and pipe-extrusion mills, and bars to the wire mills.

Sheet copper. In the sheet mills, the cakes are heated in oil-fired furnaces, after which they pass through a series of rolls. They are then cold-rolled in another set of rolls, passed forward through one set and back through another, each pass reducing the thickness of the sheet and increasing its length, the process being continued until the desired thickness is reached. The final sheet product, by various treatments, may be either hard- or soft-tempered.

Copper wire. In the manufacture of copper wire, bars from the refinery are placed in a preheating furnace until they have reached the proper rolling temperature. They are then fed to a rolling mill, to be reduced in diameter and elongated. The bar then passes to intermediate and to finishing rolls, becoming smaller and smaller in diameter, and getting continually longer until it is finished as a wire rod in coils. The rod in turn goes to the wire-drawing machines, where it is pulled through a series of dies, each smaller than the last. Copper wire can be drawn as fine as, or even finer than, .008 inches in diameter. For making wire to be furnished in long lengths, it is necessary to join a number of rods, which is done by brazing them with silver solder before drawing. A sufficient number of rods are brazed so as to produce any length of finished wire which may be required.

Copper tube. Often, copper tube is manufactured by means of a piercing mill. Here a heated billet encounters a steel point on a long rod. Rollers give the hot metal a powerful forward motion, forcing it over the point and forward over the rod. A thick and irregularly shaped tube is thus formed. An extrusion process for producing tubes is also used, as is a method of utilizing cast cylindrical shells. The tubes are then drawn through dies for further shaping, and the tube becomes smaller and the walls become thinner until the product has been reduced to the desired size.

Throughout these processes, annealing is required at certain stages, or where the metal gets too hard from working. The manufacturer also cleans and otherwise finishes his product.

Alloys of Copper

Brass. The most common and the most generally useful alloy of copper is brass, which, as stated earlier in this chapter, is a mixture of copper and zinc. No standard rule governs the proportion of these metals in brass, although copper must be dominant. The proportions will vary in accordance with the eventual use to which the brass is to be put.

Importance of brass manufacturing. Just as the United States leads

the world in the production and refining of copper, so, too, is it dominant in the manufacture of copper and copper alloys. This great American industry, employing more than 100,000 workers, had its birth with the turn of the nineteenth century. There had been some brass manufacture in the United States prior to the Revolutionary War, but even though there had been copper production in America—in Massachusetts, very soon after the landing of the Pilgrims—England insisted on dominating the field.

Location of the American brass industry. The American brass industry had humble beginnings. It started in the Naugatuck Valley of Connecticut, near which, at that time, were some small copper mines. Here land was too poor to permit profitable agricultural development, and the inhabitants were forced to manufacture as a means of livelihood. The brass industry once having started there, this location eventually became the center of the industry, in line with the time-tried rule that the community that first develops a particular line of activity holds that position because of familiarity with the technique involved and the proximity of trained workers. Today the city of Waterbury is the brass center of the country. Bridgeport also is important for its brass-manufacturing plants; and during the past 20 years, several large brass- and copper-manufacturing plants have been established in the Middle West. The products of these plants include rod, wire, sheet, strip, pipe, and tube.

Bronze. Bronze is a mixture of copper and tin. By the varying of the quantities of tin and copper, the qualities of bronze may be greatly changed; in general, the more tin is used in the mixture, the harder and more brittle will be the resulting metal. The percentage of copper used is seldom less than 80 per cent.

Just as there are varieties of brass, so are there varieties of bronze. Some brasses contain a percentage of tin; some bronzes, a percentage of zinc. This is highly desirable in many instances, as, for example, in the manufacture of bronze hardware, which must be turned out by machine, the copper and tin mixture of so-called "true" bronze being too brittle for proper working.

Other copper alloys. The various copper alloys produced include, besides brass and bronze, nickel-silver and special alloys that are fabricated into the usual shapes as well as into special shapes—such as extruded molding and hot-pressed parts.

Economic Significance of the Copper Industry

Copper and its alloys are used for the manufacture of a wide variety of articles, numbering many thousands. These include everything from large special parts for condensers or similar machinery to clocks, vanity cases, screws, hardware of all descriptions, hub caps for automobiles, bicycle pumps, and even street-car tokens.

Detroit is the center of the automobile and truck industries, which in an average year, consumed approximately 250,000,000 pounds of copper and its alloys. This industry is second only to the electrical industry

as a consumer of copper. Because of the rearmament program, the production of automobiles for ordinary use will decrease, but the production of tanks, trucks, and other military vehicles will probably more than offset this decrease.

Copper and its alloys are essential in national defense. Because of its ductility and resistance to corrosion, brass is the preferred metal for shells and cases. Copper and brass are also employed for timers, detonators, driving bands, etc. As the uses for copper and brass in marine construction are legion, the metal is of great importance in the Navy. When actual war occurs and communication becomes a vital factor, and because both radio and wire communication involve the extensive use of copper. the metal here too assumes a major role. As in the past, the present defense emergency has called for the rapid expansion of copper- and brass-fabricating facilities, and new production peaks are being reached.

The present increase in consumption has been due to numerous factors, but to a great extent to electrical and similar developments for which copper is peculiarly fitted. In the automobile, building, air-conditioning, radio, and mechanical-refrigeration industries, as in the general extension of the light and power industry and similar fields, large quantities of the metal have been consumed in various forms

Copper in power generation and transmission. About 40 per cent of the copper used in this country today goes into the electrical industry. Whether the electricity is generated by steam or by water power, the coils or windings of both the stationary and the rotating parts of the generating apparatus are made of copper. Copper commutators, collectors, and cables convey the energy to the station bus, where the current, generated by the various machines in the plant, is collected and distributed to proper outgoing lines. These buses and the current-carrying parts of the switches and circuit-breakers are also made of copper. In the generators themselves, copper alloys are used in the bearings to carry the load of the rotating part. Many other uses of copper and its alloys are found in other incidental equipment.

The voltage at which the current is generated usually is too low for transmission for long distances. Therefore it is "stepped up" by transformers that raise the voltage to the desired level. When this energy reaches the point at which it will be distributed for use, the voltage is "stepped down" by transformers similar to those in the generating station, and the current continues its path over other copper wires and through distribution transformers until it goes into its final service.

The transformers used to increase or decrease the voltage consist primarily of two separate coils of copper wire. The current from the generator passes through one of these coils and forms a magnetic field that induces a current in the other coil. At present, the transmission voltage normally is not less than 60,000, and often it is as high as 220,000 or more volts.

Copper as a factor in communication systems. Copper also plays an important part in our modern communication systems. The world

today has in service approximately 41,000,000 telephones. The United States has more than half this total. All of the telephones in the world —in North and South America, Europe, Asia, Africa, and Australia—are, in a sense, on a single line; that is, it would be possible in normal times for 1 telephone subscriber to communicate with 40,000,000 other subscribers. The copper requirements for such a vast system can be appreciated by the realization that the present wire mileage of the Bell System alone is over 89,000,000 miles. This wire mileage measures more than 3,500 times the distance around the world at the equator, or nearly 375 times the distance between the earth and the moon. Nearly 96 per cent of this wire mileage is contained in cable.

Not only this, but the telegraph services of the world employ 5,000,000 miles of copper wire and the earth is belted with more than 30,000 miles of copper submarine cables.

Copper plays an important part in radio communication. Based on an estimate of over 50,000,000 radio sets in use in this country, the amount of copper contained in them would be in excess of 150,000,000 pounds. Approximately 36,000,000 pounds are required annually in the production of new sets, under normal conditions. Copper is used for such parts as shielding, transformers, speaker coils, wiring, and antennae; and in the sets themselves, brass also has numerous uses.

Another, but little thought of medium of communication in which copper alloys are used is the pneumatic tube, which has come to replace runners for interoffice communication in large establishments. Rustproof brass tubes frequently are installed in large buildings during the early stages of construction, and remain in service always smooth and bright. Between 50,000 and 200,000 pounds of brass go into the pneumatic-tube systems of some of our large buildings.

Copper and railroad transportation. The railroads of the United States have in service today more than 1,000,000,000 pounds of copper. Most of this is in the form of one of its many alloys.

A steam locomotive, commonly thought of as entirely of steel, employs much copper. Most of it is used in the form of bearing metal for the axles and for the rod brasses, and at other points where moving surfaces may wear and a reduction of friction is desirable. Brass also is used for valves and for the injectors that supply the boiler with water. A modern locomotive may contain more than 3 tons of copper, and at least 200,000,000 pounds of copper are in service in all the locomotives in this country.

Railroad passenger cars and Pullmans also make extensive use of copper and its alloys. Much of this is used for bearings, of course, but a great deal of the interior trim is made of copper alloys, and the lighting systems depend on copper wire to carry the current. Unless this electricity is supplied from a generator on the engine, each passenger car or Pullman has its own generator. Copper tube is also being used to an increased extent for air-brake lines.

Copper and marine transportation. Copper is the oldest metal on the seas. It has been used in shipbuilding almost since the beginning of historic time. In 1929, the remains of a galley of the Roman emperor, Caligula, were uncovered after 1,000 years of immersion in Lake

Nemi, Italy; and it was found that the vessel had been fastened together with copper nails and spikes. These were in a perfect state of preservation.

The rise of the great sailing fleets, both merchant and naval, brought into use much copper and copper alloys. Sailing ships were copper-sheathed to protect the woodwork beneath the water line and to minimize fouling by marine growths. The old-time armed ship carried brass or bronze cannons.

In modern ship construction, copper and copper alloys are indispensable. The world's shipyards, in an active year, require approximately 100,000,000 pounds for various uses in merchant tonnage alone. A large modern vessel may use as much as 3,000,000 pounds of copper, brass, and bronze.

The metal goes for many details of ship construction, including wiring, piping, bearings, hardware, propellers, decorative trim, galley equipment, navigation instruments, porthole frames, and shaft sleeves.

Copper and automobile manufacture. Another large market for copper is in the manufacture of automobiles. The largest single use, of course, is the radiator, which may be of copper or brass. The electrical system—including the generator, starting motor, and the ignition—requires much copper.

Figures collected by the American Bureau of Metal Statistics show that, in a normal year, in which automobile production ranges between 3,000,000 and 5,000,000 cars, the consumption of copper by the industry is in excess of 200,000,000 pounds.

Use of copper in the building industry. Building construction, next to agriculture, is the nation's largest industry; and into it every year go surprising quantities of copper and copper alloys.

The first use of the metal in building, many years ago, was for the ornamentation of temples and cathedrals. Apparently, the metal attracted the interest of early architects more because of its beauty than of its lasting qualities; but in time, these qualities came to be recognized, and the consumption of copper has steadily increased as the quality of buildings improved. It is significant to note that, during the years from 1925 to 1940, inclusive, the amount of copper used in buildings for every dollar spent for construction in the United States was more than doubled.

As far as we know, the oldest copper roof in America is on Christ Church in Philadelphia, and it has been in service for over 200 years. Copper roofs now are being put on dwellings as well as on public buildings. The highest structure yet built by man, the Empire State Building in New York, consumed more than 1,000,000 pounds of copper and brass.

Closely associated with the roof of a building are the flashings, valleys, gutters, and downspouts. Copper generally is accepted as the ideal material for these purposes, because of its ability to resist corrosion.

Scarcely a worth-while building is erected today without the use of copper or brass pipe or copper tube for water-supply purposes, both hot and cold. Architects and property owners have recognized the wisdom of using these metals for this purpose, even though there may be a

slightly higher initial cost, on the ground that original installation will make expensive replacements unnecessary. Within the last 20 years, America's consumption of copper and brass pipe and tube has multiplied almost eight times.

One does not have to tax his imagination too greatly to obtain an idea of how much copper, brass, and bronze go into a building in other ways. Copper wire leads to every electric outlet, to every telephone connection, to every electric bell; copper radiators, saving space and adding beauty to a room, are attached to the copper tube of the hot-water heating system; lighting fixtures are of bronze, doors swing on bronze hinges, and locks are of the same enduring metal.

In recent years, copper and its alloys have been used more and more for the exterior ornamentation of buildings. The metalwork done in vertical construction between pillars, in spandrels, has been developed to add beauty to design, as well as to lighten the load and eliminate high masonry costs. Band courses and mullions are growing in popularity. For these, because of their ability to resist the action of the elements, copper and copper alloys have come to be considered the ideal metals.

In this connection, it may be said that the architect has been provided with a range of texture and tone attainable with no other metal. Not only are varicolored brasses and bronzes available for this purpose, but the period since the First World War has seen the development of lead-coated copper, which is what its name implies, namely, copper coated with lead. Lead-coated copper may be had in the light metallic gray of newly cast lead or the almost black hue of old lead; it may be smooth in texture or rough.

Other uses of copper. Mechanical refrigeration probably could not have made its forward strides had it not been for the service of copper and copper alloys. Behind the spotless porcelain doors of the modern electric or gas refrigerator is the intricate cold-making device, its operation dependent largely on the use of these metals. The rapid heat-transmitting qualities of copper and its resistance to corrosion by the refrigerants have caused its adoption for the evaporator and condenser. In this field alone, the consumption of copper and copper alloys amounts to more than 50,000,000 pounds every year.

Similarly, a new and rapidly growing industry, that of air conditioning, is already a heavy consumer of these metals. It is anticipated that, within the next few years, cooling apparatus like that commonly in vogue in theaters will be more or less universal. Here again copper has been an important factor in the progress. The annual consumption is now about 15,000,000 pounds.

The development of copper radiators, to replace the bulky and frequently unsightly ones now so commonly used, has developed an important field. The workability and heat conductivity of copper have made it possible to reduce radiator size as well as to give ornamentation to this necessary feature of every room. Already the consumption of copper in radiator construction amounts to many million pounds a year.

It is thus obvious why copper so richly merits the designation, "man's most useful metal."

19

The Lead Industry

Early history of lead. Lead is one of the oldest, most useful metals known to man, but little can be said of its original discovery. It is one of the six prehistoric metals. The metal was known to the ancients and is mentioned several times in the Old Testament.[1] "Thou didst blow with thy wind, the sea covered them: they sank as lead in the mighty waters."[2] Lead was also considered as a lucrative commodity of trade by the ancients. "Tarshish *was* thy merchant by reason of the multitude of all *kind* of riches; with silver, iron, tin, and lead, they traded in thy fairs."[3] The British museum houses one of the oldest known pieces of lead, which is believed to have antedated 3800 B.C. The Romans used lead to make water pipes by folding sheets of the metal and soldering the seams with an alloy of lead and tin. In fact some of the lead pipe installed by the Romans at Bath, England, is still in use today, conveying water. During the fifth century, B.C., the Greeks operated the lead mines at Laurium, and later in the third century, B.C., the Romans carried on extensive lead mining operations in Sardinia and in Spain. During the Roman occupation of Great Britain, they also exploited the lead deposits of that country. Lead compounds were used by the Romans. Dioscorides describes a material which was undoubtedly litharge, and Pliny spoke of a substance which was later known as red lead, while white lead was well known to Geber during the eighth century, A.D.

Thus, down through the ages, lead has been a useful metal to mankind.

Lead in the United States

Production and consumption. The United States has always been fortunate in possessing important and extensive resources of lead. As a matter of fact, the production of lead from American mines is roughly about one third of the total world production, a proportion which exerts an extremely important influence on the world market but does not, and cannot, control it. The domestic output is ordinarily only sufficient

[1] *Job* 19:24 *Numbers* 31:22.
[2] *Exodus* 15:10
[3] *Ezekiel* 27.12.

for domestic requirements and, unlike the copper miner, the lead producer does not depend upon the export market to take a part of his output.

Gradual and steady development of the domestic lead mining, smelting, refining, and fabricating industries has been of inestimable importance in the development and prosperity of our country. Many a fortune is based upon the lucky discovery and exploitation of Western lead deposits, not to mention utilization of the metal subsequently. At the same time, the histories of most American lead mining camps is replete with tales of discouragement, and technical or financial obstacles overcome. The struggles of the lead industries have not been far different from those of many others.

Ever since the Civil War the use of the nonferrous metals has grown at such a rapid rate—except during the decade between 1930 and 1940—that occasionally the disturbing thought arises: "Where is the world's supply of metals to come from 10, 20, or more years from now?" Former President Hoover, back in 1908, then a practicing mining engineer, confessed himself doubtful of the ability of the world to find an adequate supply of copper, lead, and zinc in 20 years. But it has always been forthcoming, and there is little reason to worry over the potential supplies of the metals for a great many years to come.

TABLE I

STATISTICS OF LEAD PRODUCTION AND CONSUMPTION IN THE UNITED STATES[1]

Lead Production From Domestic Ore

Year	*Tonnage*
1870	18,000
1880	95,725
1890	139,720
1900	260,918
1910	375,402
1920	476,849
1929	672,498
1930	573,740
1939	420,967

Lead Consumption[a]

1936	633,550 short tons
1937	678,700
1938	546,000
1939	667,000

Lead Exports and Imports[a]

	Exports	*Imports*
1936	18,313 short tons	23,893
1937	20,091	41,131
1938	45,866	64,366
1939	74,392	87,564

[a] *American Bureau of Metal Statistics.*

[1] Source: *Statistical Abstract of the United States* (1931).

Lead, its rising importance. Lead is ordinarily one of the cheapest of the common nonferrous metals, either just a little higher or a little lower in price than zinc. At one time it was considered to be merely a by-product of silver mining and smelting operations, being so much surplus from precious metal operations, but constant change in industry, particularly the establishment of new businesses, furnished steadily widening outlets for this useful metal. Since 1920, prices of all nonferrous metals have been greatly disturbed, but lead generally ruled at higher prices than before the First World War in the 1920's and often lower in the 1930's.

Qualities of lead. When all is said and done, lead is a queer metal. It is heavy, soft, and extraordinarily durable under ordinary atmospheric conditions, and it furnishes numerous chemical compounds of great usefulness in modern life. In fact, the physical and chemical qualities which lead possesses have enabled it to secure a remarkably diversified outlet, a very desirable situation for any product. White lead, red lead, ammunition, storage batteries, lead-covered cable, pipe, and solder are some of the familiar lead products.

Change in the utilization of lead. A striking change has occurred in the relative importance of the major activities for lead in recent years. Since 1921 lead has definitely drawn away from its dependence upon the white-lead industry—and consequently the paint business—as its most important market, and has turned to two essentially electrical applications for its principal consuming outlets, storage-battery manufacture and cable covering. It is fortunate for lead that these two relatively newer uses have grown rapidly in recent years, for the white-

TABLE II

USE OF LEAD IN THE UNITED STATES

(In Short Tons)

	1929	*1939*
White lead	119,700	75,000
Red lead and litharge	30,000	57,200
Storage batteries	210,000	198,000
Cable covering	220,000	74,400
Building	96,000	50,000
Automobiles	18,000	8,900
Railway equipment	5,700	[a]
Shipbuilding	300	[a]
Ammunition	41,100	42,300
Terne plate	4,200	5,400
Foil	39,800	21,800
Bearing metal	33,000	12,800
Solder	37,000	20,000
Type metal	18,000	14,000
Calking	31,500	16,000
Castings	18,000	7,500
Other uses	50,000	63,700
Total	972,300	667,000

[a] Included in "Other uses," below.

lead market has gradually declined, owing to intense competition from other paint pigments, such as lithopone, zinc oxide, and titanium compounds. New uses like in gasoline antiknock compounds also have grown rapidly.

The above comparative table shows how the situation has changed.

Geographical location of lead deposits. Missouri has long held the position of mining more lead than any other state, the ore mined being galena, a sulphide of lead and the kind which furnishes the bulk of the world's lead ore supply. Missouri's lead is noted for its softness and low silver content, which makes desilverizing unnecessary for much of it. Idaho and Utah are the next two most important lead-producing states, followed by Oklahoma, Kansas, and Colorado. The lead in the entire Rocky Mountain Belt is noteworthy for its intimate association with silver and to a minor degree with zinc, and is generally found in vein formation The Missouri deposits occur in limestone and are low in grade, requiring large-scale development and operation.

Producing Commercial Lead

Concentration of complex ore. There was a time, only a few years ago, when it was next to impossible to concentrate low-grade complex ores economically—that is, ores consisting of an intimate mixture of copper. lead, zinc, and other minerals. In those days every effort had to be made to mine a lead ore as "clean" as possible for fear of the penalties or charges exacted by the smelter for treating a lead ore containing zinc and other impurities. Although it is still desirable to mine lead ore having a simple composition, the concentration of complex ores has reached a state nowadays permitting extremely efficient separation of the valuable mineral constitutents of complex ores. The means by which this is done is known as selective or differential flotation, a marvellous improvement in the concentration of metallic ores, contributed during the past 20 years.

The flotation process. Flotation itself is nothing more or less than the treatment of a finely ground ore with water to which a small amount of pine oil and other chemicals have been added. The entire mass is agitated continuously with air with the result that oily bubbles of air form and rise to the surface. These bubbles carry along with them particles of the valuable metallic constituents of the ore—that is, galena, sphalerite, pyrite, and so forth—whereas the waste material, or gangue, sinks to the bottom of the flotation machine. The process is a relatively low-cost means of separating the valuable from the worthless parts of the ore. By virtue of much experimentation, certain chemical compounds and technique have been evolved whereby it is possible with flotation methods not only to make the separation between metal-bearing minerals and gangue but also to separate the metal-bearing minerals into their respective components, galena from sphalerite, and so forth. This process is known as "selective flotation."

Significance of the flotation methods. The result of the flotation process has been to add greatly to the available mineral resources of the world, for it has made commercially practicable the exploitation of ore deposits formerly considered impossible to work at a profit.

Smelting and refining plants broadly scattered. Inasmuch as lead is mined in the Middle West and in the Far West, the smelting and refining plants are well scattered. They can be found on both coasts, along the Mexican border, along the Canadian border, and in the Middle West. Smelters are usually built close to the mining districts, while the refineries are often located with the sale and distribution of the refined lead in mind.

In this connection the railroads have established what is known as "refining-in-transit rates," which permit shippers of crude-lead products to procure a rate from source to destination which is less than the rate from source to refinery plus the rate from refinery to destination. In other words, the rate permits the shipper to transport his materials to the refinery, have it refined, and subsequently marketed on an over-all freight rate which takes into consideration the interruption in the flow of the material to the market when it is refined.

Lead smelting. The ease with which the heavy metal can be melted has had a lot to do with the fact that the metallurgy of lead reached a high degree of perfection at an early date. Ordinarily the lead concentrate, after preliminary roasting and sintering to remove most of the sulphur contained in it, is treated in a blast furnace, which is nothing more or less than a vertical furnace having provision for the entrance of a blast of air to accelerate the combustion and chemical action going on within the furnace. When the blast furnace is tapped, the lead flows out into a pot and is sent to the refinery in the form of crude bullion.

Lead refining. Lead bullion is treated not only to remove impurities but also to recover its gold and silver content. The process most frequently used in refining crude lead bullion is known as the "Parkes process." This process depends for its action partly upon the relative melting points of lead and the metallic impurities, such as copper, sulphur, and arsenic, which are often found with it. The crude bullion is slowly melted and some of the impurities rise to the surface as a dross and are skimmed off. After the dross has been removed, the temperature is raised and air is admitted to the furnace. Under these oxidizing conditions other impurities, such as tin, arsenic, and antimony, are eliminated, partly as a fume. To remove the silver a little zinc is added to the lead. Then the peculiar ability of zinc to dissolve the silver is manifested and a zinc crust forms on the top of the pot, which is removed and which will be found to contain nearly all silver. There is also an electrolytic process that has been developed for the refining of lead, known as the "Betts process." It is especially useful to remove bismuth from the lead.

Grades of commercial lead. There are three principal grades of lead ordinarily produced, known as "corroding lead," "common, or desilverized, lead," and "chemical lead." Corroding lead is a lead suitable for

conversion into white lead. It is the purest commercial product. A high degree of purity is necessary so as not to discolor the pigment. Chemical lead finds its chief use in the manufacture of sheet and pipe and cable sheathing, where a high degree of durability is demanded.

Marketing. The market points for pig lead are principally New York and St. Louis. Intermediate points are based upon either of these markets, the prices quoted consisting of the New York or St. Louis price plus freight. Although the price of lead generally moves slowly, it is open to the free play of the laws of supply and demand, and has fluctuated considerably in the last few years. A London quotation, as established on the London Metal Exchange, exerts considerable influence on the domestic market.

Uses of Lead

Main uses of lead. Although the two main uses to which lead is put today are comparatively modern developments—that is, cable sheathing and storage battery manufacture—many outlets for the metal date back a century and more. Thus lead pipe, sheet, ammunition, and white lead are old and trusted commercial articles that have retained well-established markets for a long period of years, but the stress of competition in some lines, such as white lead, from other materials has hampered the steady growth of many markets for lead.

Storage batteries. To begin with the largest application first, storage batteries, those useful electrical power sources, have grown in use principally in pace with the manufacture and sale of automobiles. Nevertheless, dozens of everyday applications of lead storage batteries in trucks, locomotives, motorboats, power plants, and radios show that the market for batteries is by no means confined to one large outlet. If anything, this use of lead should grow, but its increase will not require a directly proportional amount of new lead because a large quantity of secondary or scrap metal is reclaimed each year from old batteries and used over again.

Cable sheathing. The progressive development of the second largest use of lead, cable sheathing, has been little short of phenomenal. It is allied to the growth of the electrical industries, particularly the telephone industry and the distribution of power. In this application three qualities of lead—that is, its pliability, durability, and low cost—have made the metal desirable. All of us are familiar with the common city sight of a reel of telephone cable being installed underground. The lead cable sheathing protects the rather delicate paper-insulated wires comprising the body of the cable from moisture and a breakdown of the insulation.

The telephone cable. Although large amounts of lead-covered telephone cable are used in cities, the development of long-distance telephoning has made necessary the stringing of long lengths of lead-covered cable in toll lines between cities to furnish dependable long-distance telephone service free from interruptions by storms and other disturb-

ances. The interconnection of radio networks with nation-wide distribution of programs has also helped to increase the use of telephone toll lines.

The power cable. Power cable is also an important application of lead sheathing. Larger and larger voltages are being transmitted underground. Buried transmission lines of 66,000 volts are common in large cities. Two underground lines at 132,000 volts have also been constructed. It is safe to say that the development of underground power transmission will soon permit carrying current at voltages equal to those now attained by overhead transmission lines.

Looking into the future, it would appear that the tendency to bury telephone and power lines will continue and that the outlet afforded lead by this field of usefulness will consume increasingly large amounts of lead, not alone in the United States but in Europe as well.

Chemical compounds. Lead may readily be converted into valuable chemical compounds, of which the commonest ones are white lead, red lead, and litharge. White lead has long held the preëminent position of being the best single paint pigment. It is the most satisfactory of all pigments for outside painting. In the last 20 or 30 years the intensive development of cheaper pigments, such as lithopone, has given white lead unusually severe competition, and has heavily displaced its use for interior painting. The unexcelled properties of white lead for making paint should always insure furnishing an important market for lead itself.

Red lead is the standard pigment for protecting iron and steel.

Litharge, an oxide of lead, finds wide application as an ingredient of storage-battery plates. It is a very useful chemical compound, and is used in the manufacture of varnish, pottery, rubber, glass, and the refining of oil.

Lead for ammunition. Lead is the traditional war metal. Its comparatively high specific gravity is utilized to advantage in the manufacture of ammunition. In peacetime, sporting arms for hunting, trap shooting, or target practice consume sizeable amounts of lead, but with the almost complete settlement of the United States and extinction of frontier life and much game, the demand for sporting ammunition will probably not show much growth.

Lead in building construction. Owing to its unsurpassed durability, lead is used in building construction for leaders, gutters, roofing, and flashing, but there is much room for improvement in the extent to which it finds such employment, for the merits of the metal do not seem to be so well appreciated by builders and architects as those of competitive materials. In England the reverse is true, lead being favored at the expense of other nonferrous metals.

Lead in chemical industries. The chemical industries annually use large amounts of lead to construct apparatus which will resist the corrosive action of many common chemical compounds, such as sulphuric acid. Stimulation in the production of rayon has caused large tonnages of lead to move recently into rayon plants to aid in making the fabric.

Even gasoline uses lead as an antiknock ingredient, a use which is growing steadily.

Alloys of lead. There are many useful alloys of lead. Some common examples are solder, an alloy of lead and tin, type metals, and bearing metals, all of them performing inestimable services to industry.

Enough has been shown to indicate that lead is an almost indispensable metal with a wide variety of functions. There is good reason to believe that the use of lead will expand continuously as additional methods are devised for using its valuable characteristics.

Reclaiming Lead

At the present time a factor of great moment in the lead situation is the growing importance of secondary, or scrap, lead as a source of raw material for the manufacturer. Not only have methods for the recovery of lead from scrap material been strikingly improved in the last 10 years, but the collection and smelting of secondary lead has become a well-organized industry, in some cases, as an adjunct to and under the close supervision of the virgin lead smelters. Of course there are products, such as red- and white-lead paints and ethyl gasoline, from which the lead is irrecoverable, but others, as for example, the lead type of storage batteries, use a large amount of reworked lead. In the storage battery industry alone there is a huge circulating load of lead estimated at over 100,000 tons annually. Other industries also furnish important sources of old lead. As a consequence, for every 3 tons of new lead mined, it is believed that about 1 ton of old lead is reclaimed.

Looking far ahead, there will come a time when an even greater effort will be made to reclaim old metals, owing to the progressive exhaustion of existing mineral deposits—which can only be mined once—and the failure of new discoveries to keep pace with the ever-growing world demands for metals.

Legislation Affecting the Industry

Legislation is vitally important to the lead industry. It is concerned not only with the ordinary legislation governing the conduct of business in the United States and relating to taxes, welfare, and other subjects, but is also concerned rather vitally in legislation having to do with customs matters, as the tariff and its administration. All lead products enjoy protection without which the industries would today be shut down. The tariff does not, however, prevent competition by American manufacturers in export trade because they can use the drawback provisions of the tariff law which permits them to purchase their raw material in the best foreign market, pay the duty on importation, and upon exportation of the manufactured product receive a return of the duty from the Government.

The use of the drawback is not the only means which the American manufacturer may use in order to hurdle the tariff on his raw materials

when he competes in an export market. He may also operate under the provisions of the customs law which permit manufacturing-in-bond. Briefly, these regulations provide that fabricators of exportable products may establish a bonded manufacturing plant to which they may bring their imported raw materials, free of duty, converting them to a finished form and exporting the resultant product to whatever market they expect to reach. Hence, the distinction between the manufacturing-in-bond provisions and the drawback is that, in the former, duties are never collected on the raw materials, whereas in the case of the drawback a duty is collected only to be refunded on exportation of the manufactured product. Fabricators of lead products generally prefer to use the drawback because it is a little easier to employ for intermittent export operations and does not involve the governmental red tape necessary in setting up the machinery to work under the manufacturing in bond provisions. By liberalizing the drawback laws in 1930 Congress has made them a more useful tool for the exporter.

20

The Zinc Industry*

Zinc from Mine to Market

Zinc is one of the most important of the metals. It is not an alloy but a base metal, with many valuable properties and great adaptability. Belonging to the nonferrous metal group, zinc cannot rust.

Zinc is frequently used in conjunction with other metals, and then its identity may be more or less concealed. For example, the large volume of iron and steel products which are zinc-coated (galvanized) as protection against corrosion represents one of the chief uses for zinc. Look for it in brass, of which zinc is an essential constituent, yet so far as the eye can see, the zinc is invisible.

Remarkable changes occur in the appearance of zinc as it is converted by successive stages from ore to industrial and consumer products. In the ore, the zinc mineral looks like specks or streaks of dark impurities. After the ore is crushed and milled, the resulting rich zinc mineral concentrate is a brown, resinous, granular or powdery product; and when smelted and cast into slabs or ingots, it assumes a soft, silvery gray color.

In other products of zinc even more drastic changes occur. Zinc oxide, for instance, which is particularly important as a paint pigment and as a rubber ingredient, is a white, fine powder which gives no hint of its relationship to the base product.

It is probably for these reasons that, while the importance of zinc is fully recognized by industry, the average consumer fails to realize the wide application of zinc and its many useful functions.

Early history of zinc. The history of zinc dates back to very ancient times. In fact, most references on the subject point to an idol found in the prehistoric ruins at Dordosch, Transylvania, testing 87½ per cent zinc, as the oldest piece of zinc in existence. Mention is also made of bracelets filled with zinc, discovered in ruins dating back to 500 B.C. on the Isle of Rhodes.

It is generally accepted that the ancients knew zinc as a separate metal; but down through the Middle Ages its identity was apparently lost, although in those times brass was made from zinc-bearing copper

ores without the presence of zinc being realized. Paracelsus (1490 to 1541) was probably the first to refer to the metal and name it "zinc." Asia was responsible for the introduction of metallic zinc in Europe in the sixteenth century, where it eventually became known as "spelter," a trade name which persists to a certain extent even in present times. The smelting of zinc got under way in Europe during the eighteenth century and was well established by the end of that period. The year 1850 dates the beginning of zinc smelting in the United States, but the record of production commences with the year 1860. Since then, the United States has become the largest producer and consumer of zinc in the world.

Consumption. Modern life demands great quantities of zinc. The annual consumption in recent years, if distributed equally among the entire population of the United States, would represent as much as 9½ pounds per person. This takes into consideration the metal alone, and does not include a substantial tonnage of other zinc products also derived from ore; but, even so, the consumption of zinc in the United States is greater than the consumption of other nonferrous metals such as lead and aluminum, except copper.

In world sales zinc ranks third among the leading nonferrous metals. Figures for 1938 are as follows:

Metal	*Tonnage*
Copper	1,938,667
Lead	1,879,460
Zinc	1,751,870
Aluminum	584,879

In volume, as measured by cubic feet, zinc ranks first by a wide margin. Zinc, being lighter than copper and lead, exceeds both in number of cubic feet used. The above 1938 tonnage figures are converted as follows:

Metal	*Cubic Feet*
Zinc	8,000,000
Aluminum	7,200,000
Copper	6,950,000
Lead	5,660,000

This prompts the question, just where does all this zinc go? For what is it used? Here is a diagram which shows some of the many highways and byways which zinc follows from the ore as mined, down to industrial and consumer uses.

The table on page 448 is an estimate of the quantities of zinc used in industry. The figures shown illustrate the large tonnage employed in the principal uses of the metal.

The Flow of Zinc From Mine to Market

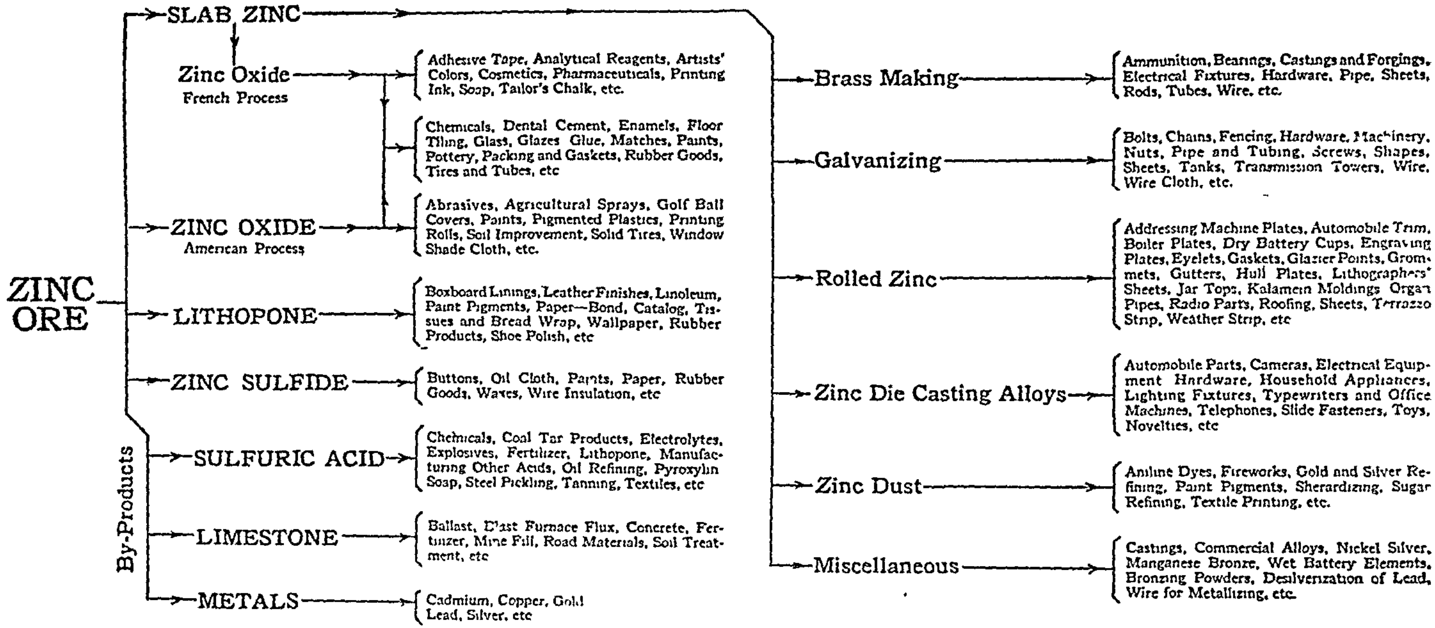


Fig 1 This diagram shows the primary derivatives and by-products of the reduction of zinc ore, and a partial list of their many and varied applications.

TABLE I

CONSUMPTION OF ZINC IN ITS PRINCIPAL USES[1]

(In Tons)

Galvanizing:		
Sheets	147,500	
Tubes	43,000	
Wire	30,900	
Wire cloth	7,000	
Shapes[a]	46,600	
Total		275,000
Brass		175,000
Rolled Zinc		62,000
Die Castings		84,000
Other Purposes[b]		30,000
Total		626,000

[a] Includes pole-line hardware, hollow ware, chains, and all articles not elsewhere mentioned.

[b] Includes slab zinc used for the manufacture of French oxide, zinc for wet batteries, slush castings, the desilverization of lead and sundries, wire for metallizing, and so forth.

In addition, there is a large quantity of zinc pigments—such as zinc oxide and zinc sulfide—produced directly from ore, and other zinc products—such as zinc chloride, zinc sulfate, and some zinc dust—made from secondary zinc, all of which will be referred to later.

A short description of the principal uses referred to above may help to develop a better understanding of the properties and functions of this indispensable metal, zinc.

Zinc in Galvanizing

Zinc as a protective coating. The iron and steel industry is the chief single outlet for zinc. Iron and steel will rust; so, for certain uses, they must be covered with a protective coating. For this purpose zinc is superior to all other metals. The United States Bureau of Standards states that zinc forms "by far the best" protective metallic coating for the rustproofing of iron and steel. In recent years, 42 per cent or more of all the zinc metal consumed in the United States has been used in zinc-coating, or galvanizing.

Zinc is well adapted for coating purposes, for it has a relatively low melting point and it is a comparatively simple matter to secure a tight bond between the zinc coating and the iron or steel base. Furthermore, there is another important reason why zinc is considered first choice as a protective coating. As iron stands below zinc in the electrochemical series, a coating of zinc provides iron and steel with perfect electrolytic protection against rust. This protection is so effective that even though there be a small exposed area on the base metal, the attacks of the elements will be directed first to the zinc coating, the base being shielded from corrosion so long as sufficient zinc remains. It is because of these

[1] Source: *American Bureau of Metal Statistics Yearbook* (1939).

properties that zinc takes precedence as the ideal protective agent for iron and steel.

Methods of galvanizing. In the coating process, called "galvanizing," any one of several methods may be followed. The one most generally used is the "hot-dip method," in which the product to be coated is first pickled, or cleaned, in a bath of dilute acid and then immersed in molten zinc. The zinc adheres to the base metal in a smooth and even covering and usually gives the finished article a crystalline, "spangled" appearance.

Zinc coating by "electrodeposition" has made considerable progress in recent years. The improvements in the process are reflected in the several new and important electrogalvanizing plants which have been put into operation. So far, these later developments of the electrolytic method have been applied to the production of galvanized wire and galvanized strip steel. The electroplating of zinc coatings on various and sundry articles is commonly practiced in metal finishing shops, and here again new processes featuring bright finishes have widened its scope.

Zinc coatings are also applied in the form of a spray by means of a "gun" which employs zinc wire or powder. The zinc is melted in the process and sprayed upon the surface to be coated. This method, known as "metallizing," is particularly applicable in the case of structures already erected and large objects which are of such size that it is impracticable to hot-dip them. Railroad bridges, large tanks, ships, and barges are examples.

"Sherardizing" is still another coating process in which articles, more generally small finished parts such as nuts, screws, and bolts, are placed together with zinc dust in a revolving container. Thus, in intimate contact and in the presence of heat, the articles are zinc-coated. A variation of this process, using flaked zinc instead of zinc dust, is called "hot galvanizing."

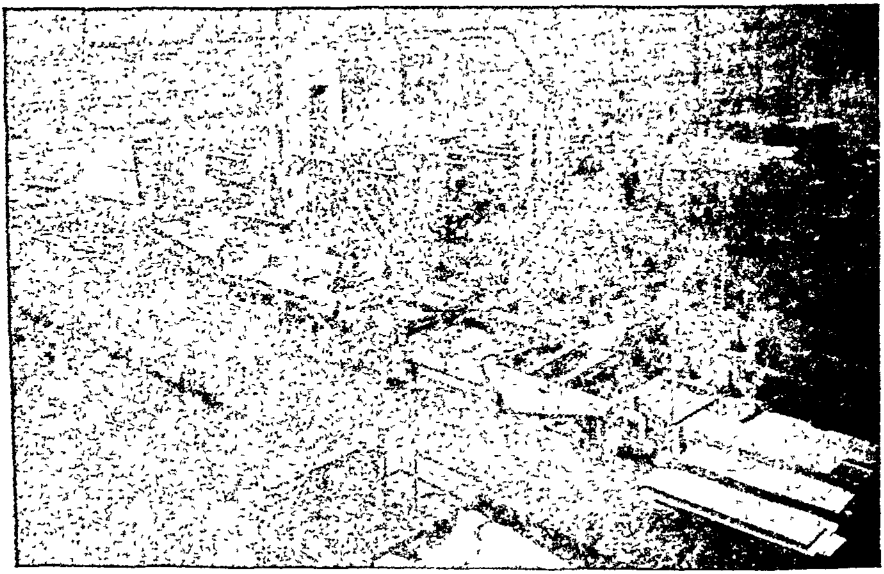
Galvanized sheets. It will not be out of place to enlarge upon the subject of galvanized sheets, as they represent the principal product of the galvanizing industry and the largest single use for zinc. Originally, the coating, or galvanizing, of sheets was done by dipping the sheets by hand into vats of molten zinc. Nowadays, while the essentials of the hot-dip process previously outlined are unchanged, specially designed machinery has developed mechanical and automatic features. These refinements have, among other things, greatly aided temperature control and have substantially stepped up the speed of the operation. In the meantime, considerable attention has been directed toward the improvement of the quality and properties of the coating itself, and progress along these lines is promising.

Galvanized sheets, which are sometimes called "galvanized iron," are one of the popular roofing materials in the United States. All types of structures, from garages and farm buildings to the largest industrial plants, may be roofed securely and attractively, as well as economically, with galvanized sheets. The annual production of galvanized sheets is

about 1,500,000 tons. These sheets are not entirely used for roofing purposes, for they have many uses, but each sheet carries its protective coating of zinc.

It would be better if, instead of "galvanized," they were called "zinc-coated" sheets, for many people are quite unaware of the fact that these sheets have zinc on them, nor do they know of the importance of the coating and how necessary it is that this coating be heavy enough to stand the wear and tear of the elements.

Tests made by technical authorities have demonstrated that there is a direct relationship between the weight of the zinc coating and the length of service life. It is a well-established truth that the heavier the



Courtesy, Aetna Standard Engineering Company

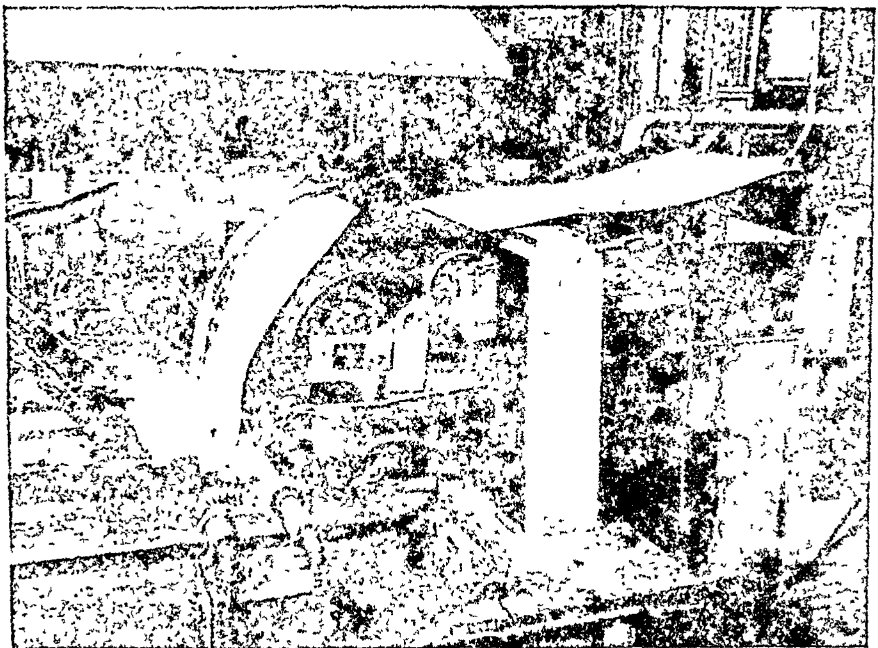
Fig 2 A modern sheet-galvanizing machine.

zinc coating, the longer the life of the product it protects. In the eyes of the average consumer, the service-life of a product fails when rust appears, and this point may be indefinitely deferred under normal exposure conditions, provided the zinc coating is sufficiently heavy.

The American Zinc Institute is an organization of producers of zinc. One of the purposes of the Institute is the development of information about new and improved uses of zinc and zinc-coated products and the distribution of this information to the consumer. The Institute neither makes nor sells any product; it is primarily an educational organization. Several years ago, it started an educational campaign centered upon the farm market, for farmers use millions of galvanized sheets every year on their barns and sheds and also on their houses. This campaign features the Institute's "Seal of Quality" which steel manufacturers are licensed,

without charge, to stamp on all galvanized sheets which conform to rigid specifications as to quality and which carry a full 2-ounce zinc coating.

Galvanized wire. Galvanized wire is another important product of the steel industry. The durability of wire is dependent not only upon the base metal, but more particularly upon the zinc coating which protects it from corrosion. The farmer uses large quantities of galvanized wire in the form of fence, because fencing is a factor in profitable farming. The railroads are also large consumers of galvanized wire and fencing to insure their right of way. Wire rope and cable require the use of much galvanized wire; the building of the new Golden Gate Bridge



Courtesy, Aetna Standard Engineering Company

Fig. 3. A coated sheet emerging from the zinc bath.

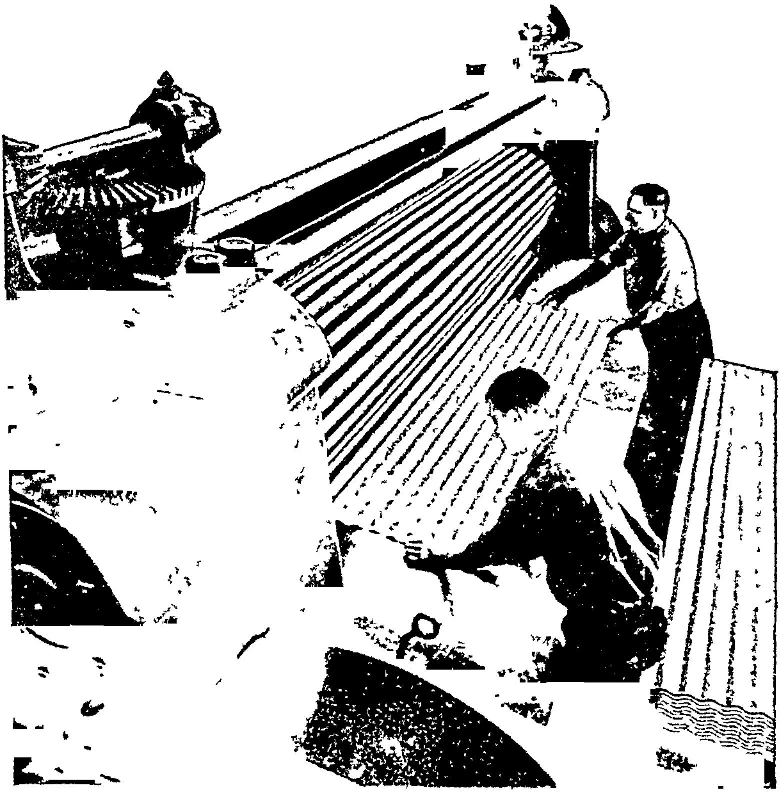
in San Francisco called for the use of 80,000 tons of galvanized wire in the bridge cables alone. Telephone companies, too, use large quantities. Fortunately, newer processes and improved practices have resulted in the application of heavier zinc coatings by some of the manufacturers, with a general tendency in this direction.

Reference has already been made to the more recent developments in the electrogalvanizing process. Figure 6 shows an important step in the production of galvanized wire by electrodeposition.

Other galvanized materials. Apart from galvanized sheets and wire, there is a great variety of zinc-coated or galvanized products and there are hundreds of uses for them Galvanized corn cribs, water tanks for

the farm stock, galvanized water pipe, much miscellaneous equipment for farming, and a great deal of the farm machinery must have its protective sheath of zinc if it is to stand up.

For household uses there are the galvanized pans and pails, the garbage can, the refrigerator, and other kitchen equipment in use every day; but some do not realize that it is the zinc coating which makes these articles serviceable. Zinc-coated window screens protect the



Courtesy, Inland Steel Company

Fig. 4. A galvanized sheet emerging from the corrugating rolls.

household from insects and pests; galvanized leaders and gutters drain the water from the roof. Many of the route markers and signs on the highways are galvanized. A new metal highway guard rail is zinc-coated; and where drainage is necessary, metal culverts, galvanized to protect them from rust, are frequently installed under the roadbed.

Zinc in Brass

Zinc is an essential constituent of brass. There are many types of brass and the proportion of zinc varies accordingly. To avoid going

into fine details, it may be said that average brass contains about 30 per cent zinc and 70 per cent copper.

Brass pipe is highly desirable for water supply systems and in the construction field generally. The use of brass in the automobile industry and in the electrical field are examples of some of the principal uses. Other examples are brass buttons, brass plates, brass hardware, brass cartridges, brass castings, and brass in the arts. The important part which zinc plays as an integral portion of this useful alloy is best proved by the fact that 175,000 tons was the total used in brassmaking in a recent 12-month period.

Rolled Zinc

Slab zinc rolled into sheet and strip form has a great variety of uses, the largest being for the production of zinc cans for dry batteries. Here the zinc can functions not only as a container but also serves as an active

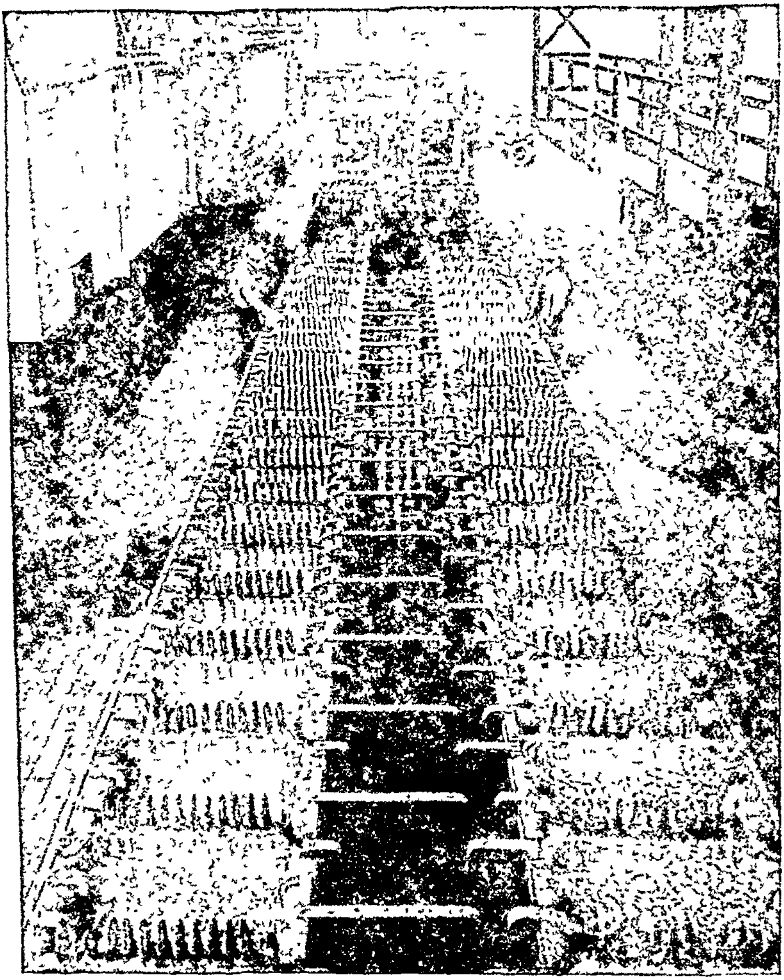
Fig 5. A distinctive mark adopted by producers of galvanized sheets to indicate a standard, extra-heavy zinc coating. This is used on galvanized roofing and siding where long service is desired.

chemical element of the cell. Tops for Mason jars, washboards, and weather stripping also consume large tonnages. In the automobile it is used for trim, in accessories, and in brake linings. The printing trade and the modern newspaper use photoengraving plates made of zinc for half tones and line cuts for illustrations. The development of photolithography has also greatly extended the use of zinc in lithographic plates. Heavy-gauge zinc sheets or plate are installed in steam boilers to protect them from corrosion; in this manner, zinc safeguards the marine boilers of the United States Navy. Zinc sheets are used in the construction field for roofing and flashings when long service is desired. Zinc roofing does not stain the house walls and paint trim. Extremely thin sheets, or zinc foil, are used for wrapping and also for insulation purposes.

The range of products made from rolled zinc includes such articles as shoe eyelets, glazier points, and organ pipes, and is so wide that it is impossible here to give a complete list.

Zinc in Die Castings

The outlet for zinc in die castings is one of more recent development. Long and painstaking research was required to find zinc alloys particularly suitable for use in die castings. The alloys employed for this purpose contain a minimum of 93 per cent zinc, with small quantities of aluminum, copper, and magnesium.



Courtesy, U. C. Tainton

Fig. 6. Electrolytic cells for plating wire with zinc. Each cell is 110 feet long and utilizes current of 40,000 amperes.

Zinc alloy die castings are made by forcing the molten metal under pressure into steel dies, where it instantly solidifies in the exact form or shape desired. These castings are sharp and clean-cut, requiring practically no machining, and can be plated, painted, or lacquered with practically any type of finish desired.

In the search for suitable die-casting alloys, a very high quality zinc was found to be necessary, so the research chemists and engineers developed a zinc over 99.99 per cent pure. This development greatly improved the physical properties of die castings and opened up many new fields of use. The result is that within a comparatively few years the quantity of zinc in die castings has reached a substantial tonnage.

Zinc alloy die castings continue to be popular in the automobile industry. More applications are found in some cars than in others, ranging from 50 to 100 castings. They vary in weight from ½ ounce to 24 pounds and are used for both decorative and functional purposes. The weight of castings per car varies from 25 to 100 pounds, depending on the make.

For several seasons, zinc alloy die-cast radiator grilles have played an important part in the design of the new automobile models. Inside hardware, such as door handles, robe rails, and heater cases; lamp brackets and radiator ornaments on the outside; carburetors, fuel pumps, and other functional parts under the hood, are now made of zinc alloy die castings and used in many makes of cars.

The use of these castings in other directions, too, is widening all the time Small tools, check protectors, typewriters, meat grinders, and other office and store equipment, household appliances such as kitchen mixers and vacuum cleaners, novelties, and toys are all examples of some of the directions in which this expansion of use can be found.

Zinc Pigments

A considerable tonnage of the zinc mined goes into the zinc pigments zinc oxide, zinc sulfide, and lithopone, which are white, and the gray pigment, zinc dust.

Paint is the largest single use for zinc pigments. For exterior and interior paints, enamels, lacquers, and industrial coatings, manufacturers find in white zinc pigments such desirable properties as great durability, tint retention, hiding power, resistance to ultraviolet rays, good gloss properties, and controlled chalking. Practically every outside paint on the market today contains a percentage of zinc oxide. The zinc sulfide pigments possess tremendous hiding power, which makes them especially useful in interior finishes of all types.

Rapidly increasing in popularity is the zinc pigment known as metallic zinc powder or zinc dust. Metallic zinc powder and zinc oxide together make the pigment of a rust-preventive paint which is especially suitable for painting iron and steel and galvanized surfaces. There are a number of special metallic zinc paints manufactured for use as metal primers,

specially formulated to meet unusual conditions such as priming parts of steel ships and bridges, and metal used in refrigerating plants and air-conditioning equipment.

Zinc oxide is essential to the rubber industry. The millions of automobile tires, truck tires, bus tires, and inner tubes carry a substantial amount of zinc oxide. In the operation of truck and bus pneumatic tires large quantities of heat are generated and the presence of considerable zinc oxide is desirable to give such tires low heat generation, good heat dissipation, and good reinforcement. In pneumatic balloon tires, zinc oxide aids in reinforcing and in preventing tread cracking. Both zinc oxide and zinc sulfide are also used to give color to white side walls. And zinc oxide is a valuable ingredient for the reinforcement of rubber hose, tubing, insulated wire and cable, rubber boots and shoes, surgical rubber, and a host of rubber specialities. Zinc sulfide and lithopone are used in some of these products to provide a high degree of whiteness.

The ceramic industry is another large user of zinc oxide. In the production of tableware, enamelware, and glass, zinc oxide imparts good color, gloss, and opacity. Zinc oxide also helps to give these products greater resistance to shock caused by sudden changes in temperature. Its presence is also beneficial in preventing the crazing of pottery and the chipping of enamel from iron.

Zinc oxide finds a wide use in the manufacture of products such as ointments, face powders, talcum powders, and sunburn cream. The zinc oxide used for these products is of exceptional purity, smoothness, and whiteness. It is nontoxic and is opaque to ultraviolet light. This type of oxide is of interest to the manufacturer of skin creams and powders for preventing the penetration of the sun's rays, which causes sunburn.

Zinc oxide and lithopone are used with the coloring pigments in the base of linoleum, and they are the chief white pigments in the paint which forms the decorative and wearing surfaces of both printed and inlaid floor coverings.

The zinc pigment, lithopone, is used in oilcloth and shade cloth in the paint coating which is applied to the cloth by a rolling operation Good color, opacity, and washing properties are the chief benefits derived through the use of lithopone.

Zinc sulfide pigments are used in the manufacture of paper to provide high opacity, good color, and brightness. These pigments are used chiefly in bond papers, bread wrap, and envelope stock.

Zinc Salts

The zinc salts, such as zinc chloride and zinc sulfate, are useful in a number of fields. Zinc chloride is used as a wood preservative, in soldering flux, dry batteries, vulcanized fiber, and oil refining. Zinc sulfate is employed in orchard sprays, by electrogalvanizers, printers and dyers of textiles, in the rayon, glue, and paint and varnish industries.

Other Uses

The foregoing is by no means a complete list of all the uses of zinc and its products. It is impossible to describe all the applications. To the many old applications, new ones are being added constantly. However, the uses covered are the principal ones in point of tonnage used, and thus give a good picture of the consuming end of the zinc industry. The chart on page 447 indicates the range of the use of zinc, although even this is necessarily incomplete.

Production

In turning to the production end of the zinc industry, the purpose is to describe in outline the methods by which zinc and its products are mined, smelted, and processed. This is not intended to be a technical treatise; therefore much of the detail is omitted.

In the mining of zinc ore, thousands of men are employed. In the process of smelting the ore and converting it into the various forms in which it is used, many more thousands earn a livelihood. Zinc as a mine product represents millions of dollars in value. Millions more are added as it completes its course through the smelters, plants, and workshops which convert zinc into marketable goods.

In 1860, the production of primary zinc—that is, metal from ore—in the United States was at the rate of about 800 tons a year. In 1900, 124,000 tons were produced. 1917 was the peak year with 670,000 tons. The nearest approach to this figure was in 1929, when the production reached 625,000 tons. Since that date production has been as follows:

Year	*Tons*
1930	498,000
1931	292,000
1932	207,000
1933	307,000
1934	364,000
1935	421,000
1936	492,000
1937	557,000
1938	446,000
1939	507,000

Zinc at the Mine

According to the *Minerals Yearbook* of the Bureau of Mines, zinc is mined in 19 states. The approximate percentage of the total production of recoverable zinc mined in recent years is listed on the next page.

There is also a small production of zinc ore from Arkansas, Kentucky, and Illinois.

Zinc mining involves several processes which are common to modern mining operations. The ore as found naturally is invariably a mixture of a smaller proportion of valuable minerals and a larger proportion of

TABLE II

PRODUCTION OF ZINC BY STATES

State	*Percentage of Total Production*	
Western States:		
Idaho	8%	
Montana	8	
Nevada	1	
New Mexico	5	
Utah	6	
Arizona	1	
Colorado	1	
Washington	2	
Total		32%
Central States:		
Tristate district (Kansas, Missouri, Oklahoma)	36%	
Wisconsin	1	
Total		37%
Eastern States:		
New Jersey	15%	
New York	6	
Tennessee and Virginia	10	
Total		31%

common rock minerals. It is drilled and blasted by the miners, and delivered to a mill which separates the valuable minerals as "concentrates" and discards the common rock minerals as "tailings."

The earliest zinc mining in America was done about 1850 at Franklin, New Jersey. For some years operations were sporadic and on a small scale. This deposit is remarkable in that the zinc minerals occur practically free of sulphur and the ores consist of a zinc-iron manganese mineral, franklinite, a zinc silicate mineral, willemite, and a zinc oxide mineral, zincite, in association with the rock mineral calcite. This is the only deposit in the world where these minerals occur in commercial quantities.

The separation of the zinc-iron-manganese mineral from the other zinc minerals was done in earlier days by hand sorting. The development of a magnetic method of separation for the milling of these ores made it possible to more economically recover the ores from these deposits Flotation is not employed. Gravity separation supplements the magnetic process. Operations in this district produce oxide and silicate concentrates relatively less in zinc than the sulfide concentrates but well adapted to the production of high-grade metal.

The largest producer of zinc concentrates is the Tristate District, formerly known as the Joplin District, located in adjacent portions of Kansas, Missouri, and Oklahoma. Mining operations in this district

commenced in 1850, but until 1870 were for lead only, the zinc ore minerals being discarded in ignorance of their potential worth. Before 1910 most of the mining was done in Missouri, but since 1915 the Oklahoma-Kansas operations, centering around the town of Picher, Oklahoma, have contributed the great bulk of the output. About half the Oklahoma production is from Quapaw Indian lands.

Tristate mining is shallow, the deepest mines being about 400 feet deep. The shallowness and bulk of the ore bodies make it possible to mine very low-grade ores, which average only 4 per cent metallic zinc and 0.8 per cent metallic lead.

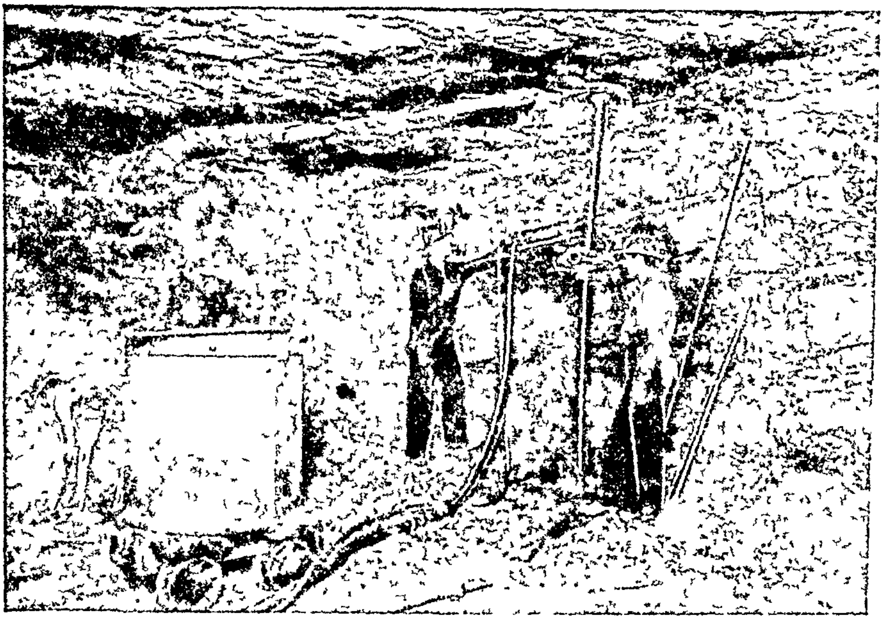


Fig 7 Drilling and ore removal in a zinc mine

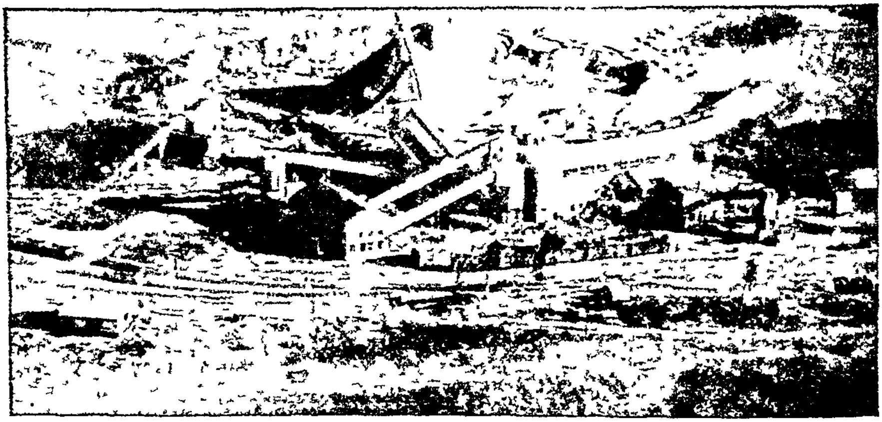
Much of the milling is done in large central mills which handle ore from many mines The largest of these mills has a capacity of 10,000 tons of ore per 24-hour day

Tristate concentrates are sulfide concentrates of unusually high grade, averaging about 60 per cent metallic zinc content They go to retort smelters in Oklahoma, Arkansas, Illinois, West Virginia, and Pennsylvania and are principally reduced to metal for the galvanizing and brass markets

The white mounds, or "chat" piles, which catch the eye of the visitor are "tailing piles," waste rock discarded in the milling operations Improved milling operations have made it possible to re-treat many old tailing piles This class of production has accounted for one fourth to one third of the concentrate output of the district in recent years but is now definitely on the decline

In the Western states, the ores containing zinc are usually complex associations of lead, copper, and zinc minerals with precious metal values which require fine grinding and flotation for their separation. The zinc concentrates are recovered in this separation mainly as a "by-product" Western zinc concentrates may contain recoverable gold and silver, which is not true of most of the Midwestern or Eastern production. These zinc concentrates are mainly sulfides, but average lower in grade than Tristate concentrates, ranging between 48 and 60 per cent zinc content. A large portion of this zinc concentrate production is smelted in the electrolytic plants for the production of electrolytic zinc metal.

The milling process consists of crushing the ore until the mineral grains are released and of following two general methods of separation. The first, which is applied to sizes between 1 millimeter and 1 inch, takes advantage of the differences in density of the minerals, the ore



Courtesy, Eagle Picher Mining and Smelting Company

Fig 8. A central mill in the Tristate zinc-mining district.

minerals nearly always being heaviest, and separates them by their different rates of settling through agitated fluid media Because large particles will settle faster than small ones, it is necessary to classify them into various size ranges before gravity separation.

The second process, which has only been in common use for about 15 years, is called "flotation." It takes advantage of the fact that certain minerals, usually those having a metallic luster, will cling to small bubbles of air if the minerals are finely ground and agitated in water with air. The affinity of "flotable" minerals for air bubbles is facilitated and controlled by the addition of small amounts of oils and chemicals. The flotable minerals rise to the top of the agitated fluids and are skimmed off as a bubbly froth.

Zinc Smelting

The concentrates as they reach the smelter contain about 60 per cent metallic zinc; but in the process of conversion losses occur, so that for

practical purposes 1 ton of slab zinc may be considered equivalent to 2 tons of concentrates.

The distillation process. In the "distillation, or retort, process," the concentrates are first roasted, and the sulphurous gases from this process are converted into sulphuric acid, the zinc being converted into a zinc oxide. The oxidized zinc concentrates are then mixed with fine coal and placed in a retort furnace fired by natural gas or producer gas made from coal. In these operations, the carbon in the fine coal inside the retort unites with the oxygen of the zinc concentrates, and metallic zinc is liberated at a temperature higher than its boiling point. This zinc passes

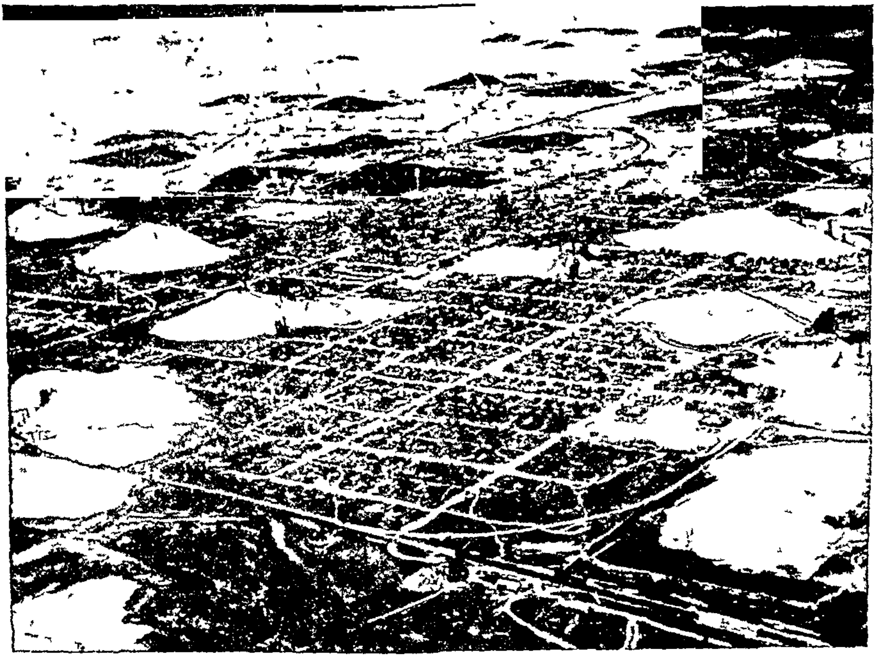


Fig. 9. Aerial view of Picher field, Tristate zinc mining district.

off in the form of vapor, is condensed to liquid form, and is then drawn off periodically and cast into slabs weighing about 55 pounds each.

There are two general types of distillation furnaces in use, namely, the older horizontal retort type and the more recently developed vertical retort furnaces.

A large majority of the zinc-smelting plants at present use horizontal retort furnaces which employ essentially the same process as was developed in Belgium at the beginning of the nineteenth century. This is an intermittent or "batch" process, rather than a continuous operation. It requires a large amount of highly trained labor. In these furnaces, the retorts are arranged in long horizontal rows and the mixed coal and ore is charged into the small cylindrical retorts, made of burnt refractory

clay, which have a capacity of about 1¾ cubic feet each. Each 24 hours, the condensers are taken down and the retorts are cleaned and recharged. Refinements and improvements in these processes have been developed in modern plants and have resulted in a higher recovery than formerly.

The vertical retort is a development of recent years and is designed to overcome the disadvantages of small retorts and intermittent charging and recharging. Two processes have been in commercial operation for some years, both of which are continuous in operation. These furnaces are charged at the top and are discharged at the bottom after the zinc

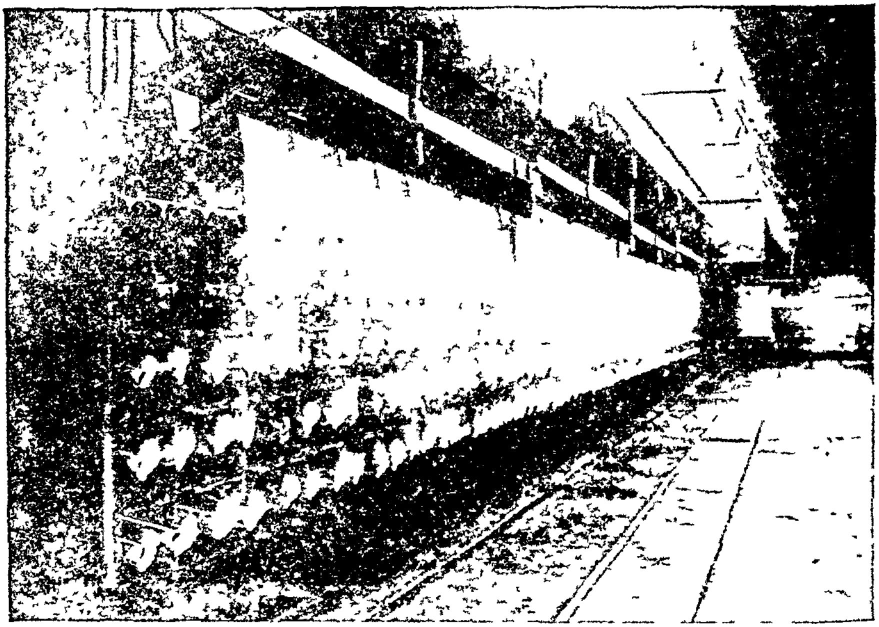


Fig 10 The front of a retort-type zinc furnace, with five tiers of retort and condenser units Each of the small tongues of flame is escaping from a vent in a condenser which is connected with a retort immediately to the rear and is packed with a mixture of roasted zinc ore, or "calcine," and finely powdered coal.

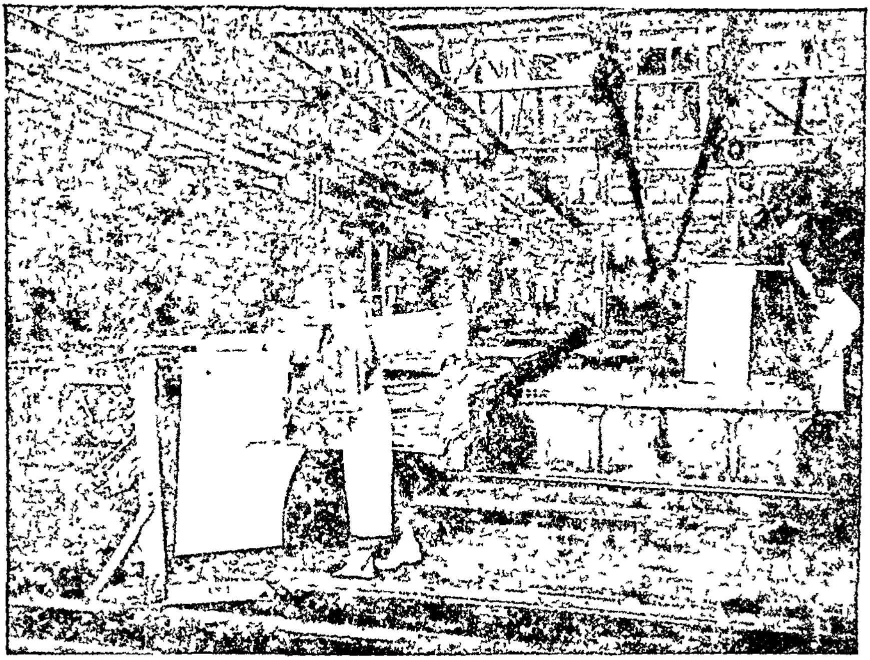
content has been distilled out. One of the processes uses the electrothermic principle, with a vertical retort heated internally by the resistance of the charge.

The grades of zinc ordinarily produced by the distillation, or retort, process satisfactorily meet the major requirements of the consuming market. The demand for high-grade zinc is supplied by a redistilling and rectifying process following the primary reduction, by which method zinc of 99.99+ per cent purity is produced.

The electrolytic process. The "electrolytic process" of producing metallic zinc was developed in the Western states in about 1915. As the selective flotation process made additional quantities of zinc concentrates available in localities where electric power is cheap, the production

of slab zinc by the electrolytic method increased and now is responsible for about one fifth of the total production in the United States. This represents the production of three electrolytic plants, two in Montana and one in Idaho.

In this process, the zinc content of the roasted ore is "leached" out with dilute sulphuric acid. The zinc-bearing solution is then filtered and purified, and the zinc content is recovered from the solution by electrolysis. The current passing through the electrolytic cell deposits the metallic zinc on the cathodes or negative poles, from which it is stripped at regular



Courtesy, Anaconda Copper Mining Company

Fig 11 Electrolytic zinc production Interior of tank house. Workman in foreground is stripping zinc sheet from aluminum starter.

intervals and then melted and cast into slabs. The zinc produced by this process is of high grade, testing up to 99.99+ per cent.

Secondary Zinc

Secondary zinc is recovered from scrap material of various kinds, including brass and other alloys. The statistics covering this phase of the industry are not considered complete, but the best available indicate that in recent years the recovery of secondary zinc in the United States has equaled from 18 to 20 per cent of the total zinc production. In addition, a considerable quantity of by-products are made from zinc-dross skimmings and ashes, the waste product from galvanizing operations.

Until very recent years, secondary zinc was an unimportant factor. Unlike other metals, zinc entering consumption is more often than not totally consumed, as for example in galvanizing, and is not recovered. At the present time, with the increasing use of zinc in alloys, secondary zinc from such sources is beginning to assume more importance.

Zinc Compounds

In addition to the production of slab zinc, an important quantity of the ore which is mined is converted directly into zinc oxide, lithopone, and various zinc salts, such as zinc chloride and zinc sulfate. These compounds, produced directly from ore, account for approximately 17 per cent of all the ore produced in the United States.

The process used in producing zinc oxide directly from ore is generally termed the "American process." By this method, oxidized ores mixed with coal are burned on a grate under forced draft. The resulting fumes pass through flues and finally into bags, which collect the condensed zinc oxide particles. Zinc oxide is also produced by the "French process," directly from high-grade metal, and in recent years there have been increasing quantities produced by this process from scrap zinc.

Lithopone is precipitated from a mixture of zinc sulfide and barium sulfate solutions. The precipitate is cleaned, dried, and roasted, and is then cooled and finely ground.

By-Products

Sulphuric acid is the main by-product of the zinc industry. This is obtained from the sulphur gases evolved in roasting the zinc concentrates. Most of the acid thus produced is sold to chemical manufacturers and oil refineries.

Other by-products include certain metals which occur with zinc in the ore bodies and which are not entirely separated in the concentration process. These include lead, silver, gold, and copper; also cadmium, for which there is an increasing demand as a bearing metal and for surface finishes and plating.

The Marketing of Slab Zinc

Slab zinc is sold according to standard specifications, which have been adopted by the American Society for Testing Materials and by industry generally.

As a matter of convenience to both buyer and seller, prices are generally quoted in cents per pound at East St Louis, regardless of the point of production. The buyer's cost is consequently the quoted price at East St. Louis plus the established freight rate from that point to destination.

The market for zinc is an international one. Normally the price outside of the United States is quoted on a London basis, where trading in

zinc on the metal exchange is active and prices constantly fluctuate.[2] It is therefore a great convenience for both buyers and sellers in the United States to have one base price upon which to make comparisons. The system of quoting prices on an East St Louis basis developed naturally because of its convenience not only to the buyers and sellers of slab zinc but also to buyers and sellers of ore generally, who may transact business with a specific relationship to the price of the metal itself. Small pro-

TABLE III

STANDARD SPECIFICATIONS FOR SLAB ZINC

Grade	*Per Cent of Maximum Impurities Allowed*				*Total for lead, iron, and cadmium*
	Lead	*Iron*	*Cadmium*	*Aluminum*	
Special High-Grade. . .	0.007%	0.005%	0.005%	none	0 010%
High-Grade	0.07	0.02	0.07	none	0.10
Intermediate.	0.20	0.03	0.50	none	0.50
Brass Special.	0.60	0.03	0.50	none	1 0
Selected.	0 80	0.04	0.75	none	1.25
Prime Western.	1.60	0.08	—	—	1.68

ducers of ore frequently sell their output on the basis of a future East St. Louis price or upon an average of such price over a period of time. This is not only a boon but a means of protection to such mining operators, who otherwise would be quite unable to follow the market for the metal and the relative value of their ore.

The East St. Louis price, which is widely published, is the price for Prime Western zinc, the type of metal most generally used in galvanizing. High-grade zinc is sold at a premium over and above the price of Prime Western, but on a delivered basis. The other grades, such as Brass Special, Selected, and Intermediate, are sold at smaller premiums above the Prime Western grade.

The zinc prices which follow are compiled from quotations published daily in *American Metal Market* for Prime Western slab zinc and indicate the trend of values over the past 30 years.

10-Year Period	*Cents per Pound East St. Louis*
1909–1918.	7.89
1919–1928.	6.55
1929–1938.	4.61

The highest price recorded was 27 cents in 1915; the lowest, 2.30 cents in 1932. In 1939, the average price for Prime Western slab zinc was 5.12 cents, the high point was 6.50 cents, and the lowest price was 4.50 cents per pound East St. Louis.

[2] With the outbreak of the war, London Metal Exchange operations in zinc ceased on August 31, 1939, and normal trading ended as the British Government initiated control of prices and supplies.

Zinc in Foreign Trade

During the War of 1914 to 1918, large quantities of American slab zinc were exported, this movement continuing through 1928, although in reduced amounts. Each year since then some slab zinc, zinc sheets and strip, zinc dust, and zinc pigments have moved abroad, but in relatively insignificant quantities.

A certain amount of zinc is exported in conjunction with manufactured products, principally in the form of galvanizing, or zinc coating, on iron and steel goods (galvanized sheets, wire, and pipe) to be shipped abroad. For such purposes, a limited amount of zinc has always been imported each year with benefit of duty drawback. That is to say, 99 per cent of the duty paid upon imports is recoverable when the products are exported.

In recent years and until 1936, the remaining imports were unimportant. In that year imports of slab zinc were 11,722 tons, and in 1937 they increased to 39,398 tons A temporary emergency explains the large rise in 1937 imports: a power shortage, resulting from drought conditions, seriously curtailed electrolytic production in Montana, and a 6-month strike reduced the output of one of the Illinois smelters. In 1938, imports of slab zinc dropped to the more normal figure of 7,486 tons.

The United States is self-sufficient with respect to zinc and zinc products. Under normal conditions the domestic industry is equipped to supply not only all industrial requirements but also the country's emergency defense needs, an important consideration, inasmuch as zinc is an essential war material.

A reduction of 20 per cent in the duties on imported zinc ore and slab zinc, which became effective January 1, 1939, came as a threat to the self-sufficient status of the United States and was a serious blow to the domestic zinc industry. These duty reductions were granted Canada in the Reciprocal Trade Agreement consummated with that country in November, 1938, but under the United States' most-favored-nation policy, these reductions automatically applied to imports from all zinc-producing countries except Germany.[3]

As a direct result of the duty reductions, zinc ore and slab zinc imports increased materially in 1939. The tonnage received from Canada was relatively small; but other countries, including Mexico, Peru, and Belgium, were responsible for the sharp rise in 1939 imports, which exceeded 1938 figures by more than 155 per cent. Mexico shipped over 59 per cent of our total imports in 1939 and thus was the chief beneficiary of the duty concessions.

Zinc production in the United States is greater than in any other one country. In the past, Belgium has been the second largest producer of the metal, but Germany (including Czechoslovakia) in 1939 finally won title to second place, Canada being fourth on the list, followed by Poland.

---

[3] At the end of 1939, additional zinc products (sheet zinc, zinc oxide, and zinc chloride) were also listed for possible duty concessions in current negotiations for a reciprocal trade agreement with Belgium.

The threatened alterations in the map of Europe may make profound changes in this picture. Nineteen countries in all are listed as producers. Large quantities of zinc ore are produced in Australia, Canada, Newfoundland, Mexico, and India, and are normally shipped to European smelters for conversion into metal.

The United States also consumes more zinc than any other country, its percentage of the total averaging about 31 per cent, Germany 15 per cent, Great Britain 14 per cent, Belgium 6½ per cent, and France 5½ per cent.

Several of the countries outside the United States have greatly increased zinc production in their efforts to become self-sufficient in this strategic metal. Germany and Russia, for example, have each trebled their production in the last 5 or 6 years. The effect of this situation upon the position of the United States in the world zinc picture has been apparent for some time. According to American Bureau of Metal Statistics figures, the United States' share in the world's slab zinc production dropped from 42 per cent in 1927 to 24½ per cent in 1932; it increased to 32 per cent in 1936 and 1937, but dropped to 26 per cent in 1938.

The United States not only has a great interest in these developments during periods of world disturbance but is also vitally concerned with the problem of safeguarding its valuable consuming market from foreign domination under normal conditions. To assure the continuation of the old-established zinc industry and the preservation of its home market, it is essential that the policy of adequate tariff of years' standing shall be reinstated and maintained. In this connection Dr. John W. Finch, then Director of the Bureau of Mines of the United States Department of the Interior, in an address on strategic and essential materials in April, 1938, emphasized the importance of preserving those industries which now provide self-sufficiency in important raw materials, as follows:

> In this connection I should like to suggest that a reduction in the present tariff on lead and zinc can hardly be considered in the public interest if viewed from the standpoint of national defense. The fact that these metals are produced in large quantities in neighboring countries is not adequate protection, as we have no assurance that supplies could be obtained from these countries in an emergency except at exorbitant cost or by military effort. It seems to me that the maintenance of the security afforded by our ability to supply our own needs of these important industrial raw materials should receive careful consideration.

21

The Glass Industry

Early History of Glassmaking

Notwithstanding the universal use of glass products in a great variety of forms, the discovery of glassmaking is clouded by the dust of centuries. Its history, however, is full of achievement, color, and romance. Beautiful as have been its products through the centuries, hallowed as are the pieces of antiquity still left to us, and marvelous as are its modern processes, the manufacture of glass never has brought great wealth in its train.

Those who have unearthed glass objects in the old tombs and buried cities of Egypt, Eastern Asia, and Greece have shown that the glassmaking art flourished widely. It is known to have died under the onrush of the barbarian hosts which overwhelmed Rome and that for long years it lay dormant, until the Venetians brought glassmaking to an art. Slowly it has spread, until now there are glass factories of one kind or another in nearly every country on the globe.

Many have tried to solve the mystery of how and when glass was first made. Pliny has given a fanciful report of an accidental beginning on the shore of Phoenicia, but discoveries since his time show that glass was made long before that. Glassmaking is related to metallurgy, and the belief today is that glass was among the first three man-made products. Pottery and metallurgy probably were closely allied to glassmaking, as they have been since. Some ancient bits of glass show evidence of having resulted from remelted metallurgical slags; others indicate a close kinship to glazing materials used on pottery.

The earliest traces of glass manufacture are found in Egypt. Glassblowers are pictured on tombs built about 4000 B.C., and beads and scarabs of glass are found on mummies buried 2500 years B.C. or at an even earlier date. Mummies found in the tombs of Memphis wore necklaces made of beads of paste glass. It is not improbable that the art is several centuries older than the first authentic traces found along the Nile.

Composition of glass. Broadly speaking, glass consists of a mixture of two or more silicates united by fusion into a homogeneous, hard mass. If the chemical denominations are disregarded, glass can be said to be

composed of sand, salt, and lime. These three materials are elemental in several forms and are found at many places throughout the world. Sand from rivers is available everywhere, salt is a common commodity, and limestone is freely distributed. It is presumed that the Egyptians used wood or peat for fuel and obtained their sand from the banks of the Nile, their salt from the Natron Lakes, and their lime, if not from crushed limestone, then as an accidental ingredient from the sand or salt

The mystery of ancient colored glass. The real mystery is, how did the Egyptians make so many beautiful colors; what agencies were used? Are these colors the result of the aging of the glass or atmospheric conditions, or were they included in the glass in melting, and how? These are baffling questions. It is probable that many productions of ancient peoples have been lost through disintegration of the glass, because glass will decompose under many conditions. From the remnants that remain, however, it is obvious that they highly valued glass. In several verses of the *Old Testament,* it is even placed in the same category as gold.

Propagation of glass art. Glassmaking spread from Egypt into Asia and was carried to artistic heights by the Assyrians and Persians From the Asian provinces and Greece it was brought to Rome. Undoubtedly, the Greeks learned the art from the Egyptians. One of the finest examples of the glass art is the Portland Vase, now in the British Museum, which in 1930 the Duke of Portland refused to sell for less than $250,000. This vase was broken by a madman about 1890 but was skillfully repaired by an English glass decorator. It shows white, or opal, glass superimposed on blue glass, with Grecian figures standing out in white on the background of blue. There are glass vases of the early Christian era in Naples, Rome, and Venice at which modern glassmakers marvel.

Rome carried glassmaking farther than it had been carried before Citizens of Rome had glass vases, goblets, cups, and large urns of glass; some even used glass in their windows. There are many evidences of a very active glass industry in Rome up to the time the Huns swept Roman civilization into oblivion. Then came years of darkness in western Europe. Except for glass for church windows, glassmaking was virtually a lost art for many generations. As Venice rose to power, with its fleets scouring the Mediterranean World, glassmaking became one of its proud monopolies. Through long years, the Venetians built up a real industry, emphasizing table glassware and mirrors. Factories were built at Tyre, and at one time whole streets were occupied with glassworks. The Venetians were so secretive that it meant death for a glassworker to leave Venice, especially after manufacturing was concentrated on the island of Murano. A Venetian law in 1474 provided that, if a glassblower left Venice and did not return, an emissary should be sent to kill him.

Despite the secrecy of the Venetian rulers, the glassworkers were stolen away one by one and scattered throughout Germany and France, and even came to England. Princes and rulers paid large sums to entice skilled glassmakers from Venice.

The road of ancient glass manufacture wound from Egypt to the Near

East to Rome, Venice, and Bohemia. Today glass is made in all civilized countries. Glass is a mark of civilization. All the older countries of Europe have glass factories; nearly all South American countries, India, China, Japan, Australia, New Zealand, and South Africa are making glass in one form or another.

Early methods of glassmaking. For centuries there was little progress in the methods of manufacturing. Until 70 years ago, the glass art had shown very little change, aside from refinements of old methods. In fact, there were greater changes in the first quarter of the twentieth century than in the 30 or 40 centuries before.

In the early days, materials were melted in clay pots and then fashioned with shears and pieces of wood while the glass was still hot. The tempering, or annealing, was done in ovens. Pots still were common in 1900, although the blowpipe, the pressing machine, and molds had been invented Glassmaking is peculiarly dependent on the ability of the workers. The expert glassmaker, through the centuries, handed down through his family the secret of what materials to use, the composition of the "batch." The blower and finishers, who shaped the glass articles, kept secret the whys and wherefores of their skill. The decorator, whether cutter or etcher, expert in colors and enamels, hid as much as possible of what he knew.

As a result of this secrecy, glass factories were small and output was limited just as markets were. Not until the dawn of the nineteenth century did glassmaking really become an industry. The progress at first was somewhat slow, but from 1860 to the present day it has been extremely swift compared with that made in earlier centuries. The tools and facilities of the old glass artisans were limited in number. The invention of a metal blowpipe, really a piece of pipe with a mouthpiece, marked the first great advance. Up until that time shaping of the glass had been done with crude pieces of wood and a pair of shears, a method still used in some places. The fusing of one glass on to another, as in cased glass, depended on the dexterity of the workman. Great goblets like those made in Venice were fashioned slowly by hand and were decorated by hand with simple tools. The wonder is not how little but how much of the products of glass factories of 250 years ago still survive. Of course, an even greater wonder is the survival of those glass beads and bottles found with the mummies buried in Egypt 2,500 years B.C.

The Glass Industry in the United States

The first manufacture of bottles and beads of glass in the United States was at Jamestown, Virginia. The English company interested in the Jamestown project shipped several workmen from continental Europe as soon as they learned that sand and some other materials were available at Jamestown. This first effort was short-lived, as were many others between 1607 and 1860.

With little or no assistance from local, state, or national government,

with no patrons of wealth to aid them, and with fierce competition from abroad to face, to say nothing of hampering legislation, American glass manufacturers carried on, some to triumphs, even if short-lived, but most to hard work and eventual financial disaster.

Early American glassmakers. After the Jamestown attempt, the first authenticated factory was that of Holmes and Southwick at Salem, Massachusetts, where the Puritans tried their hand at glassmaking. This venture was not successful, and the next glass industry beginning took place in New York in the days when the city was still known as "Nieuw Amsterdam." Glassmakers Street was the name of a thoroughfare between what are now Wall and Pearl Streets, and here there were a number of small glass factories. Among the early manufacturers in New York were the Melyers, the first glass industry family in America, and they manufactured glass "unto the third and fourth generations."

Authentic data as to factories at Philadelphia and Mullica Hill, New Jersey, prior to 1737 are lacking. It is definitely known, however, that Caspar Wistar began making glass tableware in Salem County, New Jersey, in 1739. Some of this "Wistarberg" glass survives in collections. The quality of Wistar glass was not exceeded until the famous Stiegel became active in 1765. One of Wistar's workmen, Jacob Stenger, (or Stanger) started a factory at Glassboro, New Jersey, in 1775. Glassboro still has a factory and holds claim to the honor of being the oldest glass town in the United States. Contemporary with Richard Wistar, son of Caspar, there were ventures in Braintree, Massachusetts, and in Philadelphia.

Henry W. Stiegel, first glass manufacturer of importance. Henry William Stiegel, who took the title of "Baron von Stiegel," was a German immigrant to Lancaster County, Pennsylvania, in 1750. After a few years as an assistant in an iron foundry, he became interested in glassmaking and secured financial backing. His first products were bottles and window glass, which proved successful. Stiegel saw an opportunity to build an industry, so he went to Europe to get workmen who made table glassware. He studied glassmaking in England and on the Continent, and from Germany and Bohemia brought back skilled workers, some of whom brought along their tools and molds. Ten miles north of Lancaster a new village was laid out and a factory erected to employ 125 hands. This village was Mannheim and the year was 1765. The venture succeeded, and soon Stiegel had his own retail shops in several colonies. With prosperity came personal extravagance, and then came onerous governmental restrictions from London. The pre-Revolutionary disturbances proved disastrous; the business came to an end in 1774 and Stiegel was sent to prison for debt. Products of the Stiegel factory are held in many collections, and he is acknowledged as the first glass manufacturer of importance in the United States.

Location of early glass manufacturers. During and after the Revolution, in addition to the plant of Stanger's at Glassboro, there were factories in Philadelphia, in New Hampshire, and in Massachusetts. Then, in 1785, came a great venture at New Bremen, Maryland, in which $150,-

000 were spent on the factory and town. Frederick Amelung and his workers turned out some attractive glassware, but the venture failed in 1795. Christian Kramer, who worked for Amelung, is held the equal of Stiegel as a glassmaker and the superior of Wistar and Amelung. Later Kramer interested Albert Gallatin, famous as Secretary of the Treasury, in bottle- and window-glass production along the Monongahela.

In 1798, O'Hara and Craig, who were pioneering with the use of bituminous coal as a fuel, started a bottle- and window-glass factory in Pittsburgh. In 1803, they changed to jars, decanters, tumblers, and items in blue and other colors. Soon other factories arose in New England, New Jersey, central New York, and eastern Pennsylvania. However, the War of 1812 and detrimental tariff laws were hampering factors, and most of the ventures died quickly after a year or two. Nevertheless, a few managed to worry through. The most important of these were in Massachusetts and in Pittsburgh.

One of the strongest was Bakewell, Page and Bakewell, of Pittsburgh; this company persisted for 74 years, or until 1882. It was known as "Bakewell's" and owed much of its success to the fact that it was easier to ship glass westward from Pittsburgh than to bring it from New England or New Jersey and then send it forward to the West.

Other factories were the New England Glass Company, where Deming Jarves, Enoch Robinson, John L. Hobbs, William Leighton, and William L. Libbey played important roles. Deming Jarves also started the Boston and Sandwich Glass Company, makers of "Sandwich" glass at Sandwich, on Cape Cod. He left Sandwich in 1858 and went to the New England factory. The Sandwich plant reached its height under George Washington Lafayette Fessenden, commonly known as "Lafe," but finally closed in 1884 because of strikes in the flint-glass trade.

Leaders in the glass industry. Edward Drummond Libbey, son of William L. Libbey, was probably the greatest individual figure in modern American glass production. He became proprietor of the New England Glass Company at East Cambridge, and in 1888 moved the business to Toledo, Ohio, where in 1892 it became the Libbey Glass Company. Mr. Libbey's interests widened to such an extent that, at the time of his death in 1925, he was president of the Owens Bottle Company and of the Libbey-Owens Sheet Glass Company, and the Libbey Glass Manufacturing Company was carrying on in place of the Libbey Glass Company. Since Mr. Libbey's death, the Owens Bottle Company has become the Owens-Illinois Glass Company, the largest individual maker of bottles and containers; and the Libbey-Owens Company has become the Libbey-Owens-Ford Glass Company, the largest producers of window glass.

Other famous figures of the near past and the present are James B. Lyon, who brought pressed-glass tableware production to an art; A. J. Beatty, great producer of blown glassware; and Captain John Ford, the first successful plate-glass manufacturer. Well-known families have been the Bryces, Adamses, and Bakewells for table glassware; the Bodines, McKees, and Pitcairns for flat glass; the Levises, Cunninghams, Bradys, and others for bottles and containers; the Gleasons and Gillin-

ders, and also the Macbeths and Evanses, for illuminating glassware. The Houghtons at Corning, New York, have made many important contributions to the glass art, including industrial glasses. Companion to Edward D. Libbey was Michael J. Owens, probably the greatest inventive genius the glass industry ever has known. The contributions of Owens to processes and methods in the manufacture of illuminating glass, bottles, and flat glass have been most important factors in mechanical production.

The names of John Pitcairn, Libbey and Owens, and the Houghtons mark the transition from instability to stability in the glass industry.

Economic Significance of the Glass Industry

While production of glass may not be so great an industry as the production of steel, the great variety of things made in glass and its multiplicity of uses give it a unique place. Everyone comes in contact with glass in almost every phase of daily life, and it contributes to many industries. For example, illuminating—especially by electricity—is based on glass in bulbs and tubes, just as natural illumination in homes is based on glass windows.

The transparency and strength of glass give it possibilities over other materials, and glass has the additional advantage of being easily made and formed. Glass containers make it possible to see the contents of the container and also are more attractive than other containers. The optical industry is founded on glass. Our great scientists depend upon glass in microscopes as well as on glass vessels in the laboratory; astronomy would be a lost science without glass. Few materials offer a transparent surface with strength and immunity to heat and acids, an attribute which has brought glass into constantly wider use in laboratories.

Glass has made the closed automobile possible, and the new nonshatterable glass has provided a real safety element. Modern stores would lose much of their attractiveness without glass, and even the mirror has its place in every life. Wire glass is a great fire retardant. The glassware which twinkles on the table and in the home lends beauty as well as an air of hospitality and good feeling. The removal of glass products would be a real catastrophe, because no worthy substitutes are available.

American Glass Industry of Today

Glass manufacturing is divided into three branches: flat glass and building glass, bottles and containers, and pressed and blown glassware. The first division is comprised of every form of flat glass, including mirrors and colored glass used in making art-glass windows. Bottles and containers constitute a classification that identifies itself. It is comprised of every kind of container, from small medicine or perfume vials to large acid containers. Pressed and blown glassware takes in not only glassware for the home and table, illuminating ware, laboratory and chemical glassware, but also a great range of specialties for the home,

office, arts and sciences, professions, and industry. One great factory for pressed and blown glassware produces bulbs for electric lighting, great insulators for power lines, fine art glassware, railroad-signal glass, and heat-resisting glass for cooking and serving in the home as well as for use in chemical and other industries.

Raw materials. There are some raw materials, like silica sand, soda ash, and limestone, which are used in all branches of the glass industry. Other materials are used only in one or two branches, and some for only certain varieties within a branch. Most raw materials are obtainable in the United States, although some are brought from foreign lands, such as kryolith, a material which is used in making certain forms of illuminating glassware and is found only in Greenland.

Silica or silica sand, as used by the glass manufacturer, is more than 99 per cent pure silica. Today people demand a clear glass, and traces of color are not desired in window glass, containers, and table glassware. The sand, therefore, must be almost pure silica. The great beds of it are found in Pennsylvania, near Lewistown; in West Virginia, near Berkeley; in Illinois, at Ottawa; in Missouri, near St. Louis; and in several other states. The Lewistown, Berkeley, and Ottawa deposits are the great sources of supply for most of the glass industry.

Limestone comes from central Pennsylvania, northwestern Ohio, and Indiana. Soda ash, a product of salt, is produced in New York State, in Pennsylvania, Ohio, and Michigan. Metallic oxides are used in varying amount for coloring glass Feldspar and borax toughen certain forms of glass. Feldspar comes from North Carolina, New York, and Maine; borax, from California.

Glass manufacturing centers. From Pennsylvania, West Virginia, and Ohio comes a very large proportion of all the glass products made in the United States. New Jersey, Oklahoma, Indiana, Illinois, New York, and California also produce glass in many forms. Southern New Jersey was the first great center until its place was taken by Pittsburgh. Pittsburgh, because of its proximity to the factories in the three most important states, still is the most important center of the industry. Toledo, Ohio, ranks second because it is the headquarters of three large producers. Okmulgee, Oklahoma, is another center.

Pittsburgh at one time had nearly all the glass factories, but when natural gas was discovered in central and northwestern Ohio, the factories flocked there. Indiana next came into the limelight; then followed a rush westward to Kansas. These centers were short-lived, and the last great movement was eastward into West Virginia, today the state with more glass factories than any other. West Virginia has the world's largest window-glass factory, the world's largest tumbler factory, and some of the world's great bottle and container plants.

Laboratory glassware and specialties for various purposes are centered in southern New Jersey and in Corning, New York. Pittsburgh, Toledo, and Clarksburg, West Virginia, are the centers for plate and window glass; Toledo, Wheeling and Charleston in West Virginia, and southern New Jersey, for bottles and containers; Pittsburgh and Wheeling, for

table glassware; Philadelphia, Brooklyn, and Pittsburgh, for illuminating glassware; Baltimore, for fancy containers; Elmira, New York, near where the milk bottle first was invented, and Toledo, for milk bottles. These centers are east of the Mississippi. In the Southwest, Okmulgee, Sapulpa, and Shreveport are glass centers. Centers on the West Coast are Los Angeles and San Francisco.

Reasons for the geographical location of the industry. In the past, cheap fuel was the deciding factor in the location of glass factories, but as far as can be judged from the new factories built in recent years, nearness to desirable markets is now the most important consideration in choosing a site.

Obtaining the raw materials. Sand, which forms the great part of the batch of raw materials, is found in rock form. The rock is thrown down and broken with an explosive and is then removed to a mill, where it is crushed, washed, and sized. Sand is transported to the factory in box cars, because it must be as dry as it is possible to get it. Limestone is used either raw or crushed. Soda ash is in quality of 58 per cent dense and looks like flour. It is packed in bags or shipped in barrels. Most other materials do not bulk so large as the three mentioned and are generally shipped in bags or barrels or, if quantities are sufficient, in carloads.

Railroads are the principal means of transporting raw materials to glass factories. Some plate-glass factories obtain their grinding sand from near-by streams. This is not a raw material but an abrasive, used in the manufacture of glass. As a rule, glass factories are located outside large cities, and even small amounts of raw materials, such as those used for coloring matter, must be shipped by freight and express. Those factories in large cities will use trucks where convenient.

Manufacturing Processes[1]

Window glass. Prior to 1905 production of window glass was mainly by hand methods. It was blown by skilled workmen into the form of small cylinders, which had to be split and flattened before cutting. In 1905 the cylinder machine came into use, and from then until 1915 the two methods—the cylinder machine and the hand method—competed. In 1915 the sheet-drawn machine began to operate commercially, and at the present time this method has practically superseded both the cylindrical machine and hand methods in the United States. The hand method persisted until 1924, but only in a small way after 1919. The cylinder machines are still used, but over 95 per cent of the total output is from sheet machines.

A window-glass batch has materials in these percentages: 51.80 per cent silica sand; 1.55 per cent salt cake; 15.155 per cent limestone; 20.64 per cent soda ash; 10.34 per cent feldspar. Part of these ingredients are in the cullet.

[1] The process used in the manufacture of plate glass will be discussed in the following chapter, on "The Plate-Glass Industry."

Drawing processes. One of the processes for drawing window glass is controlled by one company. This was originally known as the "Colburn process," after the inventor. In this method the glass is drawn vertically over rolls from a melting tank. The tank, like all furnace tanks, is made of clay refractory blocks. It may be able to turn out up to 250 tons of molten glass every 24 hours. In this process the molten glass flows into a "fining" chamber, leaving impurities behind, and enters a shallow section. Thence it is conducted through a pair of continuous rollers, one above and one below. The speed of the rollers and the volume of the glass decide the thickness, which may be from single thickness (14 sheets to the inch) to 1/4 inch. After ascending about 45 inches, the glass passes over a large roller and is conducted horizontally to the annealing lehr. Heat from gas burners is applied to assist the glass in moving over the bending roller. The glass sheet then passes over another system of rollers just as it enters the annealing lehr, which is upward of 400 feet in length and is a continuous chain belt.

The glass issues from the lehr in a continuous sheet up to 72 inches in width at a speed of from 2 to 6 feet per minute, depending on the thickness. It is cut into "stock sheets" about 8 feet in length. The stock sheets are delivered by overhead monorail to the cutting stalls, where the skilled cutters cut to exact size and quality.

In the other process, used by a number of manufacturers, the molten glass is drawn through a clay block, which is slotted, through parallel rows of insulated rollers to a platform about 20 feet above the "fining" chamber at the "working" end of the tank. From 6 to 8 machines are placed on one melting tank, while in the Colburn process a smaller number is used. The sheet continues upward and is annealed as it passes between the rollers. It is cut into stock sheets and then goes to the cutters. The glass has a temperature of 2,000 degrees F. in the tank, about 1,500 degrees F. as it enters the rollers, and about 175 degrees as it is cut into sheets on the platform 20 feet above the tank. A monorail system, including an elevator, carries the glass to the cutting rooms, where it either is held in sheets or is cut for boxing.

Types of window glass. In addition to single- and double-strength window glass, there is produced in window-glass factories both lighter and heavier glass in sheet form. The lighter glass is for dry plates or for use in picture framing; the heavier glass approximates plate glass in thickness and in some instance is ground and polished.

Bending and treating of glass by roughening the surface are done outside the window-glass factories in plants especially equipped for these purposes.

Laminated, or nonshatterable, glass, also known as "safety glass," is in reality a glass "sandwich." Two sheets of plate glass or of window glass, with plane surface and of similar dimensions, are placed in a huge, steam-heated press, with the laminating material, generally pyralin, between. The two sheets of glass adhere to the pyralin and will not break away from it. The glass may be broken but it will not shatter

or fly An extreme form of this glass, which is a triple-deck "sandwich," is impervious to bullets at close range and is used widely in banks.

Wire glass and special glasses. Wire glass is a sheet glass with wire imbedded in it. The glass is melted in a tank similar to that used for window glass and is poured on to a table by use of a ladle. As the glass is poured on the table, a piece of wire netting of approximate size is placed in it. It is annealed and cut into lengths. This glass is a great fire retardant and is much used in public buildings.

Heavy glass with figured surfaces for the diffusion of light is used in factory buildings and institutions. It is poured on to a table and rolled. The design is on the table, which serves as a huge mold.

Colored glass, such as that used in art windows, is melted in pots which are placed in furnaces and is blown by hand in cylinders and rolled in small pieces. The proper mixture of the batch requires skill. Duplication of colors often is most difficult because of variation in materials as well as in melting conditions.

Bottles and containers. The first bottles were generally made in factories which also made window glass. The packers and the public now demand a clear crystal glass instead of the color-tinted containers of 25 years ago. Bottles first were made by a skilled blower using a mold. Today, virtually all bottles are blown or formed by machinery.

A huge melting tank, which is fed automatically at stated intervals from storage bins carrying the previously mixed materials, supplies the glass to the machines. The number of machines served by a tank depends upon the size of the tank and the size of the ware to be made. A feeding device, operated electrically, permits the glass to drop in the form of a "gob" on to the mold. The machine generally has two sets of molds. The first forms the neck or upper part of the container, from which the glass, still hot, is transferred to the second set, the "blow" molds, where it is blown into final shape. The bottle then passes automatically to an annealing lehr. Some factories now use individual lehrs for each machine; others use a battery of lehrs for a still larger battery of machines. Factories that make large containers have from three to six huge melting tanks and can produce an enormous number of containers, not only in crystal, but also in green, blue, and amber. Extremely fancy bottles, especially for the perfume trade, still are made by hand

Production of bottles and containers is more nearly completely automatic than any other glassmaking process. Many containers are made without a human hand coming in contact with material or product until the container is inspected at the end of the lehr before being placed in a shipping carton. Synchronization of machines and perfect timing enable the manufacturer to produce, by a continuously automatic process, bottles ranging in size from small vials to those of 5-gallon capacity.

Michael Owens developed the first automatic forming machine. Others who have contributed to the speedy output of bottles and containers have been Brooks and Peiler, O'Neill, Lynch, Teeple, and Edward and W. J. Miller. Others too have contributed important links to the process of

automatic production, which begins with the batch-mixing cart and ends with the storage warehouse. It has been said that the machines of today will make a bottle, but if it is to be a good glass bottle, the machine must be fed with glass in proper amounts and condition. Therefore the glassmaker still must hold his post, so that there may be no interruption in the flow of "metal" from the melting furnace (tank) to the machines.

Extreme care is required in manufacture. Many containers for medicine, pharmaceuticals, and condiments are made for an exact content. They are filled by machinery, and there must be no variation. This demand for exact size and contents has caused many a producer to be beset with difficulties in filling an order which might run into hundreds of carloads.

Pressed and blown glassware. This branch of the glass industry covers broadly all other forms except flat glass and bottles and containers. It ranges from the common tumbler to the fine laboratory glass and optical glass, and to fine tableware and illuminating glass. All things made of glass cannot be made from the same melting pot. For each color and variety and for differing purposes there is a special glass. A glass for optical purposes is totally different from that used in a heavy ash tray of dark-green glass. Generally, factories confine themselves to one or two kinds, although there are some which make an almost endless variety of wares

Common forms of glass for table use, including tumblers, are produced automatically. Large tanks are used for melting the glass, and in general the method of manufacture is similar to that used for bottles. The lehrs used for annealing, however, are larger, and the machines are different and somewhat slower because they must handle a great range of sizes and shapes. The automatic process of manufacturing glass for table use is so effective that there are tableware plants which have produced more than 5,000 carloads in one year.

From the ordinary pressed tumbler to the finely decorated water goblet there is a wide range. In between come those articles which cannot be pressed or blown on a machine. These are made semiautomatically by skilled workmen, who gather the glass, press or blow it into shape, and finish it. In this process of manufacture, the press is the only machinery used until the annealing lehr is reached. The decoration of fine stemware and tableware is an art in itself and ranges from cuttings and acid etchings to fine gold encrustation and copper-wheel engravings.

Colored glassware. In producing colored glasses, highly skilled workmanship is required of the glassmaker, and he often is assisted by the chemist. Some factories even employ their own technical staffs A few men, like Nicholas Kopp and Frederic Carder, have a peculiar knack with colors, and the modern factory can produce as many variations as the glassmaker of old. Glassware in certain colors can be made by automatic processes and, as a result, are within the reach of all. Other colors, like ruby and deep blue, are costly to make and must be produced by hand.

The best ruby or red glass is made with the use of gold in the batch. A glass rich in lead is required for the addition of 1 ounce of gold for every 60 pounds of batch. This glass must be worked out quickly and is hard on the melting pots. A deep opaque-blue glass has 300 parts of sand, 200 of lead, 100 of soda ash, 3 of oxide of cobalt, 50 of niter, 4 of borax, and 8 of manganese. In making an emerald-green glass, iron filings often are used in a flint batch. Pulverized coke is an active coloring agent for black glass. The raw materials for topaz yellow, which has been a popular color, are: sand, 62 parts; soda ash, 7.43 parts; potash, 13 6 parts; lime, 7.43 parts; red lead, 4.95 parts; borax, 1.24 parts; saltpeter, 2.48 parts; sodium biuranate, .743 parts; and antimony, .155 parts

Forming glassware. Despite the variety in raw materials and the many purposes to which pressed and blown glass is put, the actual forming of the many kinds of glass of this type is similar. Ordinarily, a heavy piece is pressed and a thin glass is blown. In most cases a mold is used. For special laboratory and chemical glassware, great skill is required; the workman takes tubing of varying diameters and lengths and makes his glass articles over a lamp with an intense flame.

Inspection. The day has gone when "anything" would do in the glass industry. Mechanical production has made necessary absolute control of raw materials, and factories of any size regularly employ a chemist to see that raw materials are up to standard. Larger companies have technical staffs. Each step in the manufacturing process is watched carefully, and pyrometers and heat-recording instruments play an important part in controlling the temperatures in the manufacturing process.

Standards have been adopted for many glass products, and inspection of the ware for proper classification is necessary. Except in flat glass, there are few quality standards and there are no seconds. Flat glass is graded into several qualities; for bottles and containers there is only one quality. Bottles, because of the requirements of their users, must be made exactly right in shape, size, and content. As the ware passes from the annealing lehr, it is inspected. In the bottle and container field there are master measurements for each size, and the bottle either meets the factory standard or is thrown away. At the same time that it is checked for measurements it is inspected for other flaws, and it must come up to the standard laid down or be rejected.

A polariscope for closer examination of ware is used in most factories. This device shows strains and flaws not apparent in the usual inspection. Manufacturers have found it cheaper to maintain rigid inspection than to cause delay by permitting off-quality ware to be shipped. Some of the cheaper grades of glassware are not inspected closely, but this is due to the fact that the purchaser has waived rigid inspection in order to get a lower price. Scientific, laboratory, and illuminating glassware is inspected most rigidly. Factories making signal glass for railroads have a Government inspector on duty. Manufacturers have found that it pays to inspect ware closely, and often a bonus is paid workmen who maintain a high standard.

Important glass products. Plate glass, window glass, pressed and blown glassware, and containers are the important glass products. Their comparative volumes of production are shown by the following statistics for 1937. In that year all flat-glass products had a value, at the factory, of $100,938,681, as against $68,622,602 in 1935. The plate-glass production was 192,592,000 square feet. The window-glass output in 1937 was 616,566,000 square feet, with a value of $31,380,000. Table and pressed and blown glassware excepting containers, made by all processes, had a value of $86,441,000 in 1937 as compared with $67,442,258 in 1935. The 1937 total included nearly 40,000,000 dozens of tumblers, goblets, and barware, with a factory valuation of $12,564,000. Handmade tableware was worth $13,377,000 in 1937. Pressed and blown lighting glassware had a value of $22,290,000.

Glass containers manufactured in 1937, the record year of this branch of the industry, had a value of $160,646,000 at the factories. This total included beer bottles and liquorware to a total of more than 13,000,000 gross, worth $43,844,000. Containers for medicines and toilet preparations numbered more than 18,348,000 gross, with a value of $36,165,000. The production of milk bottles holds fairly steady, and in 1937 there were 2,676,711 gross worth $14,272,620.

Packing and shipping. Flat glass is shipped in boxes made for the particular sizes. These boxes or crates are made in the glass factories from rough lumber. An average carload of window glass is about 500 boxes, although the exact number depends upon the size and weight of the glass. Table glassware is shipped in barrels or in cartons, bottles, and containers, in wooden crates, or in reshipping cartons. Large manufacturers supply to users of the bottles cartons properly marked and stenciled for the product which the bottles are to contain. They also supply closures and seals, if required. Shipments generally are made in carload lots. Glass tableware and specialties are the exception to this rule, for, although they often are shipped in carloads, they also are sent in 1- or 2-barrel lots or in a number of cartons or boxes.

Marketing methods. Each of the three main branches of the industry has its own marketing methods. Flat glass, with plate and window glass predominating, is sold through distributing warehouses or wholesale jobbers, except where large users, such as automobile makers, buy direct. Some automobile manufacturers have their own plate-glass plants, just as large makers of electric-light bulbs have their own factories for bulbs and tubing. Very few packers, however, make their own bottles and containers. This ware is sold direct through agents in principal cities or through traveling salesmen. Generally it is sold on contracts of a year or more. Pressed and blown glassware is also sold through agents or traveling salesmen. Some factories have their own sample rooms in the largest cities and their own sales force for the remaining territories. Others sell only through agents, some of whom carry more than one line. Syndicates and chains, such as the 5- and 10-cent stores, are sold direct through their main buying offices. Buyers for syndicates, chains, and department stores also visit the factories once or twice a year. Many

glassware manufacturers attempt further to bring their products to the attention of buyers by participating in the annual Pittsburgh trade show in January.

Pressed and blown specialties are sold directly to the users, and in some instances a high degree of technical knowledge is required of the sales representative. It is difficult, if not impossible, for a salesman to sell both window glass and tableware because the sales outlets are different and each product requires different handling.

Export marketing. Except in bottles and containers, there is little export business. Most of American exports of glass products go to Canada, Mexico, and Central and South America. Companies doing an export trade have sales agents at important trading centers.

Exports of glass products in 1939 had a value of $10,422,000. This was the largest of any year since 1929. In 1939, containers and bottle exports were valued at more than $3,400,000, table glassware and tumblers and stemware at $1,962,000, and plate glass at $1,106,359.

With the exception of 1937, the value of glass exports had exceeded import values since 1929. This was in contrast to the trend prior to 1929. In recent years, the total overseas trade in glass products has averaged about $17,500,000.

In bottles and containers, competition in the United States comes from within the domestic industry. In certain types of flat glass, including plate and window glass, imports are a serious competitor. Table glassware competition is both domestic and foreign. The old-style factories face continuous mechanical production here and cheaper hand labor from abroad, especially from Central Europe. Except in plate glass, the total productive capacity of the country has not been used for some years. This has resulted in the abandonment of worn-out plants and concentration in the larger and more modern factories. This process has reduced the number of window-glass manufacturing companies from nearly 70 in 1920 to less than 10 in 1938.

Labor employed. The number of wage earners employed within the glass industry is 70,000. The higher wages go to the higher skilled workmen. In the table-glassware field, the highly skilled workers number 6,500. In the other branches, the skilled workers have decreased in numbers as mechanical devices have increased. There are no general health hazards in the glass industry. Accidents from molten glass or bursting furnaces have grown fewer. The decorating branch is probably the most hazardous, but precautions are taken to protect workers using cutting wheels and acids for etching and other finishing processes.

Labor relations. In the present century, the glass industry has had an excellent record in its relations with labor. In the glassware field particularly, the record of collective bargaining through joint-wage conferences between skilled workers and manufacturers goes back more than 50 years. This branch of the industry is looked upon as a pioneer in collective bargaining. The example from the glassware branch has spread to other branches of the glass industry. At present, wage scales and working conditions in the glass industry are adjusted by joint con-

ferences held annually or every other year. Nearly all the agreements provide that operations shall continue until an agreement is reached. There are instances where a year has ensued before an agreement could be made. During that period the workers continued at their places under the previous scale. However, there are a number of nonunion manufacturing companies, nearly all of them in the pressed- and blown-glassware branch.

Important legislation. The most important legislation affecting the industry is the tariff law. Because glass can be made in most countries, it faces peculiar competition from abroad The higher wages in the United States make glass products susceptible to attack from the cheap labor countries, because labor is an important factor. The introduction of mechanical production is balancing this, but the wares made by hand or semiautomatically feel increasing burdens from foreign competition. It is estimated that, if the glass tableware imported in 1930 had been made in this country, more than 6,000 additional persons would have been given employment. Foreign wares, such as table and fancy glass, give the distributor opportunity for greater profit than if he handled domestic wares, which may be the reason for the increasing importations. All that the American glass manufacturers and the workers in domestic glass factories want from a tariff law is equalization of wages. Given an equal basis of competition such as they have in their own country, they have no fears. Needed legislation includes a law keeping out of this country wares made by child labor under 16 years of age. Our own state laws do not permit child labor in glass factories, but foreign manufacturers have no such restriction.

Plant organization. A bottle and container factory will be used as an example of plant organization in the glass industry. In charge of operations is a general manager, who may be, and generally is, an officer of the corporation. He is assisted by a factory manager who works daytimes and by a night manager. The factory managers are in direct charge of production, while the general manager superintends other management details. A sales manager looks after sales, generally under supervision of the general manager. The chemist or technical man is under the general manager. Under the factory managers are the shop foremen, such as the mold and machine-shop foreman, the packing-room foreman, machine foreman, and others. The respective foremen are given control of their particular divisions and are not supervised to any extent. Except for some very large companies, glass manufacturing companies are under the leadership of men who have come up through the ranks. The factory proper, the office, and the sales staff are roads leading to the control of companies. Some families have been long in the industry, and in such cases the leadership goes from father to son, the son serving his apprenticeship some place in the organization.

Important companies. In the flat-glass field, the leading companies are the Pittsburgh Plate Glass Company, of Pittsburgh, and the Libbey-Owens-Ford Glass Company, of Toledo. These two companies are the only active manufacturers of plate glass not controlled by automobile

manufacturers. They also are large producers of window glass. In addition, the Pittsburgh Plate Glass Company has more than 70 distributing warehouses for jobbing glass and paint products. Other window-glass manufacturers are: the American Window Glass Company, of Pittsburgh; the Harding Glass Company, of Fort Smith, Ark.; and the Rolland Glass Company and Fourco Glass Company of Clarksburg, W. Va. Leading manufacturers of rough, rolled, and wire glass are the Mississippi Glass Company, of N. Y.; and the Blue Ridge Glass Corporation of Kingsport, Tenn.

The leading factors in the bottle and container field are: the Owens-Illinois Glass Company, of Toledo, O.; the Hazel-Atlas Glass Company, of Wheeling, W. Va.; Ball Brothers Company, of Muncie, Ind.; the Armstrong Cork Company and Anchor Hocking Glass Company, of Lancaster, Pa.; the Carr-Lowrey Glass Company, of Baltimore, Md.; the Knox Glass Bottle Company, of Knox, Pa., and affiliates; the Thatcher Manufacturing Company, of Elmira, New York; and the Glenshaw Glass Company, of Glenshaw, Pa.

Producers of tableware, using either pressing or blowing, or both, include: the Cambridge Glass Company, of Cambridge, O.; the Federal Glass Company, of Columbus, O.; the Fostoria Glass Company, of Moundsville, W. Va.; A. H. Heisey and Company, of Newark, O.; the Hocking Glass Company, of Lancaster, O.; the Hazel-Atlas Glass Company, of Wheeling, W. Va.; Libbey Glass Manufacturing Company, of Toledo, O.; the McKee Glass Company, of Jeannette, Pennsylvania; and the United States Glass Company, of Pittsburgh, Pa.

Leading producers of handmade wares exclusively are: Bryce Brothers Company, of Mt. Pleasant, Pa.; the Steuben Division of the Corning Glass Works, of Corning, N. Y.; and the Morgantown Glass Works, of Morgantown, W. Va.

Glass specialties, including chemical and industrial ware, come chiefly from such firms as the Corning Glass Works; the Kimble Glass Company, of Vineland, N. J.; the Rodefer Glass Company, of Bollaire, O.; and L. J. Houze Convex Glass Company, of Point Marion, Pa. Illuminating-ware manufacturers include Gleason-Tiebout Glass Company, of Brooklyn, N. Y.; Phoenix Glass Company, of Monaca, Pa.; Gillinder Brothers, Incorporated, of Port-Jervis, N. Y.; and the Consolidated Lamp and Glass Company, of Coraopolis, Pa.

Future Developments

Progress of the glass industry in methods of production has been extremely rapid since 1905, but leaders of the industry believe that the next few years will see, instead of significant changes in the mechanical methods of production, a wider use of glass products and their application to purposes not generally known at the present time. Few manufactured products are as adaptable to varied forms and colors as glass.

Use of glass in new forms for building construction is increasing. A late development is architectural glass, or glass designed especially for

particular architectural needs. Glass as a construction material is facing a future of expansion.

Most recent of the new products resulting from the inventive ingenuity of American glass technicians are glass building block and fiber glass. Glass building block first was introduced in 1935, and its acceptance and use in all forms of exterior and interior building has been widespread. Fiber glass, also made with machinery developed exclusively in the United States, is believed to have a great future as an insulating material and fire retardant.

Glass containers are more widely used today than ever before, and new uses are being found constantly. There will be a progressively increasing use of glass as containers for many products and materials. The slogan of the container manufacturers, "See What You Buy—Buy In Glass," has been effective in adding many new forms of glass containers and increased use of older forms.

In the electrical and chemical industries, the use of glass in many forms is growing. Glass products of which only a few pieces formerly were used in the laboratories now are of great importance in the chemical industry, not only in experiments but also in the manufacturing processes. Glass will be an increasing factor as a material in electrical processes.

Glassware in the home, both for utility and ornament, has a special appeal because of the many forms and colors it may assume. Its use in the home is growing steadily.

It would seem that in the past 20 years combinations and amalgamations have placed control of two branches of the industry in the hands of a few companies. Instead of further combinations, it is most probable the next 10 years will see construction of small, compact glass factories close to the sources of consumption. Each important center of population probably will have a bottle and container plant and a glassware factory. Larger companies will have production units in every important distribution area; some already are preparing for this eventuality.

The future will see a spreading out of the glass industry and additional manufacturing units in centers of population which do not now have glass factories. These newer units may or may not be owned by present large producers.

22

The Plate-Glass Industry

The rise of the plate-glass industry in this country to world-wide preeminence is one of the greatest triumphs of American industry. Today the plate glass in the windows of our stores, our homes, and our automobiles is taken by most of us as a matter of course. But back of the gleaming sheets of crystal lie decades of toil and failure, and then slow-won success against apparently overwhelming odds.

Difficulties Encountered

Many of the extensive glass-sand deposits of this country were known even before the Revolution, and there was an adequate supply of the other raw materials. There was, however, a dearth of skilled workmen; the comparatively few foreign-trained experts could not themselves man the works, and training American artisans in glassmaking required time. Then, too, the bad conditions of the roads and the nature of the product made long-haul transportation very costly, so that it was difficult to extend the market beyond the immediate vicinity of the works.

Worst of all was the steady, relentless competition of foreign glass. Through all the records of the industry in our country, from the Revolution almost to our own time, runs the story of struggle between native and European producers. The foreign hold on our markets was strong and tenacious. When necessary, foreign-made plate glass was sold below cost to throttle competition.

First Plate-Glass Plant

This strong foreign competition, combined with the conditions that existed in the country, brought about the ruin of the first plate-glass plant of any consequence erected in the United States. This plant was built in 1850 at Cheshire, Massachusetts, where there was an abundant supply of pure quartz sand. After many expedients had been resorted to, including the removal of the plant to Brooklyn, New York, the enterprise failed in 1856.

Again determined men raised the necessary money and revived the undertaking at Lenox, Massachusetts, under the name of the National

Plate Glass Company. This new venture was probably inspired by the adoption of a new method of polishing plate glass by means of a machine designed to polish marble. Members of this organization induced other men to join them, among them, Theodore and James Roosevelt of New York City, and formed the Lenox Plate Glass Company in 1865. Costly equipment was installed, with much machinery from England, but after 6 years this effort failed as had the others preceding it. The discovery of natural gas as an economic fuel attracted the plate-glass industry to many centers. Thus in 1870, the industry was established at New Albany, Ind., Louisville, Ky., Crystal City, Mo., and Pittsburgh, Pa.

The Plate-Glass Industry Established

The money invested and lost in attempts to manufacture plate glass in the United States had amounted to many millions when, in 1880, a group of men in Pittsburgh, headed by Captain John B. Ford, determined once again to attempt to establish the plate-glass industry on this side of the Atlantic. Combined with ability to visualize the future and faith in the progress of the country, these men possessed the courage to sacrifice immediate profit in order that they might build securely for the years ahead.

They recognized that the industry required such large plants, so long a tie-up of materials, and demanded production on so big a scale, in order to turn out glass which could be marketed at a profit, that they must resign themselves to a large investment of capital which might not bring returns for a long period of years. That their faith and courage were justified is proved by the fact that their undertaking prospered; very slowly, it is true, but very surely. Through their efforts the plate-glass industry in the United States was established and recognized as an individual industry.

Growth of the Industry

In the years to come, the young industry was to press forward with giant strides. Although 60 years ago the American manufacturer could not make a single sheet of plate glass in competition with European rivals, today we lead the world both in the production and consumption of plate glass. Production has increased from 17,000,000 square feet in 1900 to a record production of 213,000,000 square feet in 1937.

Manufacturing Processes

The one characteristic of its manufacture in which plate glass differs from all other types of flat glass is the fact that all plate glass is ground and polished. There are two distinctive methods of producing the original sheet, one known as the "casting process" and one as the "continuous process." The continuous process is a more recent development in the art of making plate glass

The casting process. The production of the largest sizes, which are made by casting, is a difficult and hazardous art. The melting, casting, rolling, annealing, grinding, and polishing that are part of this process involve the mining of silica and coal, the quarrying of limestone, the chemical manufacture of soda ash on a large scale, the reduction and treatment of fire clay, and an elaborate system of potmaking for crucibles —all of which require an enormous financial investment, a multitude of men, and extensive factory properties.

The melting pot, or crucible. To the layman, the most interesting and amazing feature of the casting process is the fact that the pot, or crucible, in which the materials are melted together and fused, requires years for its preparation and lasts only about 20 days in service. The long time required to produce a pot and its short life necessitate the carrying of an immense stock of pots. In large factories as many as 5,000, each weighing 3,000 pounds, were formerly kept in storage, and the space thus occupied was immense. At the present time, casting from pots is gradually being discontinued in favor of continuous rolling from large tanks, although glasses for special requirements must be made by the pot method, and a considerable quantity of standard qualities is still also produced in pots.

Each pot is capable of melting at one time 1½ tons of glass. It requires nearly a day and a night, at a temperature of from 2,500 to 3,000 degrees F., to complete the melting.

The work of making the pot begins 3 years before it is to be used. The clays, after they have been taken from the mines, are exposed to the weather so that they will disintegrate and impurities will oxidize. This seasoning process takes at least a year or two, according to conditions. The clay is then ground, screened, mixed accurately with certain other ingredients, and "pugged," or kneaded. After kneading, the clay must be stored again, to ripen, a process requiring about 6 months.

The pot itself is made by a highly skilled workman. Handwork is necessary because a slight defect, such as an air cavity, which would cause the pot to crack in the furnace, could not be detected if the pot were made by machine. The potmaker builds up his pot, layer by layer, with infinite care. The finished pot must then be stored again for 6 months or a year for its final season. When the pot is finally ready for the furnace, it is given a test baking in a heat which is approximately the glassmaking heat, 2,500 to 3,000 degrees F.

Raw materials When the pot has passed inspection, it is filled with the raw materials of the glass—silica (white sand), soda ash, limestone, salt cake, salt, arsenic, charcoal, and cullet (broken glass)—and placed in a furnace in which there is room for from 12 to 20 pots.

Melting and casting. The terrific heat of the furnace causes the materials to shrink so that the pot has to be refilled three times to insure the proper quantity of molten glass at the end of the melting.

When the melting has reached an exact point, the big pot, glowing, incandescent from the intense heat of the furnace, is grasped by huge electric tongs and lifted from the furnace. An electric crane swings the

pot over to the casting position and pours the molten glass into a trough formed by two giant rolls. The glass in each pot is rolled into a separate sheet, and a typical pot contains enough glass to produce about 800 square feet of polished plate glass ⅛ inch in thickness. By this method of manufacture, the glass sheet is formed at the rate of about 160 lineal feet per minute and the sheet is approximately 10 feet wide.

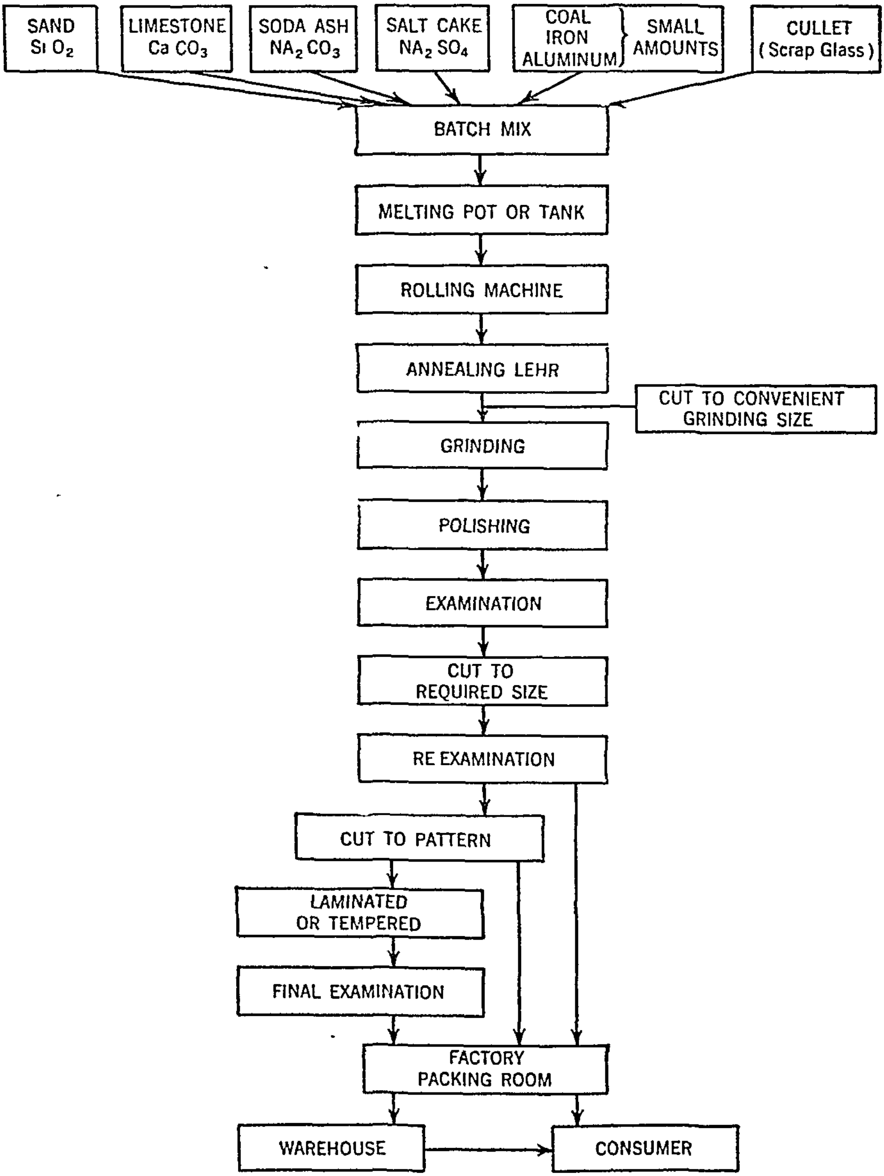


Fig. 1. Progress of raw materials in the manufacture of polished plate glass

This method, which combines casting and rolling into one operation, has almost supplanted the older process in which the melt is poured over the casting table—a cast-iron slab about 32 feet long and 20 feet wide—and subsequently flattened by a gigantic steel roller advancing across the casting table.

Annealing. Whether produced by the older or newer method, the newly formed sheet is still quite hot, even though greatly cooled during the rolling process. To prevent sudden cooling in the outer air, the plate is rushed without the slightest delay to an annealing oven, or "lehr," as it is known to the glassworkers. This lehr is like a tunnel, several hundred feet long. An electric conveyor carries the plate through this tunnel very slowly, indeed so slowly that it requires considerable time for the plate to traverse the entire length. During its passage, the plate passes through a series of varying temperatures, each a trifle cooler than the last, until it emerges at the temperature of the outer air, or cool enough to handle. This process of annealing must be carried on with the greatest care, for any irregularity in the cooling may, and frequently does, produce an internal stress sufficient to shatter an entire plate.

Grinding. The plate is now ready for the operations of grinding, smoothing, and polishing. Electric cranes again lift the plate on to the huge circular steel tables covered with wet plaster of Paris to hold the plate in place. The tables, which are on wheels, are then towed by motorcar to a place beneath the grinder.

Massive iron-shod runners revolve over the surface of the glass. As the table bearing the glass revolves, water and sand are fed under the runners, which are lowered slowly until their entire weight of 124,000 pounds rests on the glass. Under this powerful abrasive action, the surface is ground with absolute uniformity until all the irregularities in the rough glass are ground away. As the grinding continues, finer sands are substituted for the coarser grades, and during the last stages a still finer abrasive, emery, is employed, in several different degrees of refinement.

Polishing. When all the irregularities of surface have been removed and the glass is reduced to approximately the desired thickness, it is polished. The polishing machine is similar to the grinding machine, but instead of iron shoes, it carries many buffing disks of felt, each about eighteen inches in diameter. Red oxide of iron, or "rouge," as it is commonly called, the finest known abrasive, is fed under the buffing disks as they revolve. The glass is then reversed and the other side ground and polished. This polishing operation gives to plate glass its beautiful, brilliant surface.

The finished plate. Grinding and polishing reduce the original plate to half its thickness; sometimes more The material washed away is lost, and fully half the original weight of lime and soda has vanished. Upon completion, each plate undergoes a painstaking inspection for defects, and if it is not up to quality it is rejected.

The continuous process. Although the pot method of melting is still in quite general use, the compulsion of the mass-production idea has

resulted in the development of a new melting and rolling technique which is rapidly gaining favor.

The newer melting technique is very similar to the open-hearth steel-furnace practice, as originally developed by William Siemens; and the method of rolling, though originally developed for glass manufacture by Lord Bessemer of England, also found its first commercial application in the steel industry.

In the new method of glass manufacture, the batch materials are fed almost continuously into one end of an enormous melting tank, instead of being melted in relatively small individual pots. These tanks hold approximately 1,500 tons of molten glass, which is maintained at a depth of approximately 5 feet. Instead of being cast at intervals between large heated rolls as in the pot method, the glass is drawn off continuously through relatively small rolls, which must be water-cooled because of their constant contact with the molten glass. This rolling takes place at the opposite end of the tank from that which receives the raw batch. These tanks are approximately 120 feet long and are divided into two principal compartments. In one of these compartments melting takes place, and the temperature is raised to about 2,700 degrees F. in order to "boil" the glass. (The glass, of course, does not boil at 2,700 degrees F. in the same sense that water boils at 212 degrees F., but evolution of gases does take place in considerable degree.) The glass gradually flows from the melting chamber into the second compartment, where its refinement is allowed to reach a satisfactory stage without the aid of additional firing. In passing from the first compartment into the second, the glass is compelled to flow under a refractory baffle which actually floats in the molten liquid. This construction detail is primarily a precautionary measure taken in order to prevent small amounts of refractory from entering the forming rolls, the heat in the firing chamber being so intense that it is not unusual to find that drops of melted refractory brick have detached themselves from the bottom of the tank cap and fallen into the pool of glass below.

By the time the glass has reached the forming rolls at the end of the second tank compartment, it has cooled to a temperature of about 2,100 degrees F. (It will be noted that the melting and rolling temperatures are the same in both the pot and tank methods of production.) The rolls operate 24 hours per day without interruption and produce a horizontal ribbon of glass 6 or more feet in width at a rate which may be as high as 145 inches per minute, depending on the thickness. Shortly after the newly formed sheet leaves the forming rolls, it enters an annealing lehr approximately 400 feet long. From the time that the rough plate leaves the annealing lehr it is examined, cut, ground, and polished in a manner identical in every way with the treatment given to glass produced by the pot method, and since these processes have been described previously, there is no need to review them here.

However, a question may have arisen in some minds as to why it should be necessary to grind and polish a glass which has been rolled to exact thickness and with parallel surfaces. The answer is simply

that no one has yet been able to roll glass which has a surface comparable to that on polished plate. The rolling temperature is so high that the most expensive alloy will not retain a polished surface. Consequently, as the ribbon of glass comes from the forming rolls, its surface is covered with innumerable tiny irregularities, which render it entirely unsuitable for most of the purposes to which plate glass is ordinarily put. The nearest approach to the economically ideal glass which requires no grinding or polishing is modern flat-drawn window glass.

Herculite

Through the application of heat and subsequent cooling according to a special technique, it has been found possible to temper ordinary glass in such a manner that its ability to sustain a stationary load is increased four to five times, and its ability to withstand impact is increased to a much greater extent. Glass which has been subjected to this treatment is known as "Herculite."

This transformation is accomplished by first heating the glass above the annealing range (to near 1,300 degrees F.) and then suddenly and uniformly chilling the entire surface by means of a blast of air, which must reach every portion of the surface at exactly the same instant. The chilled glass is set aside, and the core, which is still quite hot, is allowed to cool gradually to room temperature. The result is a glass which appears the same as before the treatment was applied but whose physical qualities have been vastly altered. It will no longer respond to marking with a cutting wheel or diamond. Ordinary plate glass will break quite readily along the score made by a cutting wheel, but Herculite, even when deeply scratched, is still several times as strong as ordinary glass which has no score. Ordinary plate glass has a modulus of elasticity about one third that of steel, and therefore will bend three times as far under a given load. Yet we think of glass as brittle because, though easily bent, it does not bend far until it reaches the limit of its elasticity and breaks. Herculite is just as easily bent as ordinary plate glass, but it will bend so much farther because of its greatly increased strength that it is often thought of as being more flexible than ordinary glass. Ordinary glass is easily destroyed by high heat, particularly if it is heated suddenly in one area while the remainder remains cold. Herculite, on the other hand, is so resistant to heat that melted lead may be poured with impunity upon one surface while the opposite surface rests upon a cake of ice. It will withstand a temperature of 650 degrees F. for an indefinite period of time without showing signs of deterioration, and for short periods of time it will resist considerably higher temperatures. Tempering, therefore, places glass in the category of a heat-resisting material and makes possible its utility in places where temperature conditions would make ordinary plate glass wholly impractical. Herculite can, of course, be broken by the application of sufficient force, but its rupture is wholly unlike that of ordinary glass. Instead of breaking into large, irregular pieces or long and exceedingly dangerous

splinters, it completely disintegrates into cubical granules. It is not possible to break off one corner or divide the plate in any manner. Should this be attempted even on a very large plate, the farthest corner would instantly fly into small fragments of typically cubical shape. Another peculiarity of Herculite rupture is the marked tendency of particles to move in the plane of the plate, rather than to fly in all directions. Consequently, should a framed piece of Herculite be broken, it is highly probable that none of the glass would fall from the frame, even though it would be cracked throughout in such a manner as to give the effect of opacity.

It may be desirable now to reconsider the tempering process and discover why Herculite behaves as it does. It will be remembered that the heat-softened glass is subjected to surface chilling. This chill causes the surface to harden, and the soft core of the glass readily adjusts itself to the same size as the chilled surface. However, when the core later begins to harden and contract as a result of gradual cooling, it finds the previously hardened surfaces stubbornly resisting a reduction in area. Consequently, when the plate has finally cooled until both surface and core are at room temperature, the surface is left in a state of high compression, while the core is under an equal tensile stress. This condition makes it necessary to bend the plate a considerable distance before the surface at the convex side even begins to be in tension. Since failure almost invariably begins on the tension side of a flexed plate, the effective strength and the elastic limit are greatly increased by strains set up through tempering.

Polarized light will show local strain patterns when passed through a plate of glass. In the case of Herculite, the stresses are so intense that this pattern may sometimes be observed by the natural eye. This is especially true when the light which reaches the eye has been reflected from a polished surface before passing through the Herculite plate or when it is directly reflected from the Herculite plate at the angle of polarization.

The foregoing discussion will make it clear that Herculite cannot be cut or fabricated in any manner in the field. All cutting, notching, drilling, and so forth must be accomplished before the plate is subjected to tempering.

Nevertheless, it will readily be realized that this tempering process has greatly increased the adaptability of glass in many fields, and this is especially true in the province of building construction.

Laminated Glass

The process of laminating glass is another development which has taken place since the turn of the century, and probably represents the most important step in fabricating progress since the end of the seventeenth century.

About 1904, a chemist accidentally discovered that a film of cellulose nitrate would adhere to glass and prevent flying fragments in case

the glass were broken. Coincidental accidents, involving injury of persons by broken glass, provoked the idea that cellulose nitrate might be used to make a safety glass which would prevent personal injury. This idea developed slowly at the start, and its first significant application was in the manufacture of goggle lenses and gas masks.

After the end of the First World War, the manufacture of laminated glass declined for a time, until the rapid increase in automobile production made it apparent that measures had to be taken to reduce the hazard of injury from broken windshields and body lights.

The first safety glass for use in automobiles comprised a "sandwich" of two plates of glass joined to make a single unit by means of a sheet of cellulose nitrate plastic. Little was known about the reaction of this plastic to sunlight, heat, and cold; and although this first glass undoubtedly provided a valuable degree of protection, it was far from satisfactory. The sunlight rapidly caused it to change color, thus diminishing visibility and creating a distasteful appearance; subzero temperatures caused the plastic to become almost as brittle as glass, with a consequent decrease in safety factor; adhesives and laminating processes were poor, resulting in separation of the layers of glass and plastic.

But this first crude product was rapidly improved through chemical research and mechanical development. One of the most important steps in this direction was the development of a special glass having the property of selective light transmission. Through the introduction of this glass, those rays of light which caused the plastic to deteriorate were barred from contact with the plastic with only slight reduction in the transmission of visible light waves. Better adhesives were developed, and lamination was accomplished by means of hydrostatic pressure instead of unsatisfactory platten presses. Later, the use of cellulose acetate (which retains its plasticity through a wider temperature range than does cellulose nitrate) still further improved the quality of laminated safety glass and resulted in a product which seemed quite satisfactory.

However, it seems to be a fundamental characteristic of research men that they are never satisfied with any degree of perfection, and when it was found possible to produce a new plastic material called "Vinal Plastic," it was immediately discovered that this material had so many advantages over any plastic formerly used for laminating glass that its adoption was inevitable.

The strength and elasticity of Vinal Plastic is such that a sheet only .015 of an inch thick provides a suitable laminating medium for production of a superior safety glass. Although the glass fracture which occurs in safety glass made with this new plastic has the spider-web pattern characteristic of the earlier safety glasses, impact is absorbed more gradually. This feature reduces the danger of personal injury which may occur from the force of collision, a hazard which is only indirectly related to the possibility of serious cuts. Vinal Plastic is not materially affected by sunlight and therefore does not require a special glass for its protection. It may be laminated either with or without an auxiliary adhesive, since the plastic itself has the property of "wetting" the glass.

Although the idea of laminated plate glass is quite simple, a rather complex and exacting technique is required to produce a satisfactory product.

The very thoroughgoing inspection to which the glass manufacturer subjects his glass is not sufficient for the laminated safety-glass producer. For his purposes, the glass must be chemically clean. Therefore, after the glass has been cut to the shape desired in the finished article, it is passed through a continuous washing machine, where it is given a thorough scrubbing with pumice and water, dried, and prepared for further processing. There must, of course, be two companion pieces of glass for each piece of finished laminated glass.

While the glass is being made ready for lamination, the plastic is being given simultaneous preparation, the first step being subjugation to an extremely exacting inspection. Any small particles of unplasticized material are rendered plastic, and if this is not possible, the sheet is rejected or cut to smaller size. A very careful check of the composition, tensile strength, and other factors is maintained at all times in order to ascertain that the plastic shall meet the stringent requirements of the laminated safety-glass producer.

After the plastic sheet has been found satisfactory, it is cut to template, as were the companion glasses, and is almost ready to be passed to the assembly line. However, it must also be as nearly clean as is possible; consequently, it is passed through a scrubber and drier, and enters the assembly line free from extraneous dust and essentially free from static electricity. The plastic sheet is now placed upon one of the companion glasses, and the other glass is placed over all to form a "sandwich."

All of the assembly thus far has been conducted in air-conditioned rooms. Nevertheless, the assembly is again very thoroughly examined to make sure that no tiny particle of foreign material has found its way to the interior of the sandwich. The edges of the glass and plastic are brought into proper alignment, and the sandwich is now ready for the preliminary pressing. These presses were formerly platten presses, which operated somewhat like a giant waffle iron, in which heat and pressure were applied at the same time. Now, however, most of this work is done with "pinch" rolls, which squeeze the sandwich as it moves through an oven.

The final pressing of the laminated-glass assembly is performed in immense autoclaves, through which oil may be circulated under relatively high temperatures and pressures. The glass is placed on special racks which fit into the autoclave. When the autoclave lid has been securely fastened, the level of the fluid is raised somewhat over the level of the topmost plate and the temperature and pressure are gradually increased. A maximum temperature of 250 to 300 degrees F. and a pressure of about 180 to 200 pounds per square inch are attained. These conditions are maintained for a definite cycle, and thereafter the laminated safety glass, as such, is finished. Further steps to which the plates are subjected merely render them a salable article of commerce.

Excess plastic material, extruded from the edges by heat and pressure, is removed by dipping the laminated glass in acid or running the edges over a wire brush. This leaves the edges clean and ready for such edging process as may be required. If excess plastic were not removed, it would tend to clog the grinding wheels used for edging and would make this step almost impossible.

In the edging department, the edges of the glass are ground true to master template, and such special edge contours as the rounded, "pencil," beveled, and so forth are ground and polished.

After the edging process, the glass is cleaned, examined, and the label of the manufacturer is sandblasted on one corner. The glass is then given a final examination and packed for shipment.

Under slowly applied load, laminated plate glass shows a strength approximately equal to the strength of ordinary plate glass of corresponding thickness. Under impact, however, laminated glass is many times stronger than ordinary plate glass. This is due to the fact that the kinetic energy in any impinging mass is absorbed more slowly and over a greater distance, owing to the flexibility inherent in the laminated product. A piece of laminated safety glass one fourth of an inch thick will crack but will not break through under an impact which will shatter a piece of plate glass an inch thick.

The use of Vinal Plastic has materially increased the impact resistance of laminated plate beyond any value previously considered maximum.

Multiplate, which, as the name implies, is made of several layers of glass and plastic, is used regularly as protection against armed vandals. The heaviest of these armor-plate products will deflect a bullet fired from a standard army rifle.

Although sheet glass may be laminated as well as plate glass, the quality of vision is proportionately diminished. Laminated sheet glass, therefore, is not to be recommended where clarity of vision is important.

The cost of laminated plate glass has been compared to the purchase of an insurance premium. It might, perhaps, better be described as a health guarantee, because its protection against mutilation and death is preventative rather than remunerative.

Manufacturing Centers

The principal companies actively engaged in the manufacture of polished plate glass in the United States at the present time (1940) are: the Ford Motor Company, with plants at River Rouge, Mich., and St. Paul, Minn.; the Libbey-Owens-Ford Glass Company, with plants at Toledo, Rossford, and Lancaster, O., Charleston, W. Va , Shreveport, La., and Ottawa, Ill.; and the Pittsburgh Plate Glass Company, with plants at Creighton and Ford City, Pa., and Crystal City, Mo.

As is the usual case, these factories were located with a view to supply of raw materials and proximity to transportation facilities. But because of the intense heat required to melt and fuse the ingredients of plate

glass, there is also another important feature to consider in choosing a site for a factory, namely, fuel. Natural gas is the most satisfactory fuel, but where this is not available, producer gas is used.

Distribution

Plate glass is retailed to the actual consumer by jobbers or distributors, who buy in carload quantities from the manufacturer. Because of the nature of the product, packing, shipping, and storage present great problems to both manufacturer and distributor, in order to hold loss by breakage to a minimum.

Up until 1910 no American plate glass was sold in export markets, and even at the present time the amount is comparatively small. The export peak was reached in 1919 (as a result of the First World War), when over 7,000,000 square feet of American plate glass were shipped to European countries. The figures declined steadily from then on, however, till in 1926 less than 1,000,000 square feet were exported, as compared to imports of over 26,000,000 square feet. From 1927 on exports again increased, until in 1935 the total was over 5,000,000 square feet, about 3 per cent of domestic production for that year.

Uses

Many important uses have been found for polished plate glass, chief of which, of course, is glazing. In this respect, plate glass performs a function that cannot be equaled by any other glass. It gives absolutely true vision without distortion or interference. Its body is almost as clear as the open air itself, and its surfaces are free from the familiar waves, swirls, and curlicues of sheet glass. Viewed from any angle, objects seen through plate glass appear exactly as they are.

Daily we pass the store fronts that line the business thoroughfares of cities the world over. We hardly give a thought to the plate glass, because we look through it at the display in the window, hardly seeing the glass itself. We see the goods displayed in the window as clearly as if the glass were not there; yet the goods are protected from wind, rain, and theft.

In world-famed office buildings, plate glass is specified because of its beauty, clarity, durability, adaptability, and resistance to wind. Architects, builders, and home owners are realizing more and more the value of plate glass in residence windows and doors. It is being used for this purpose to an extent undreamed of a few years ago.

Plate glass for glazing has found its largest field, however, in the automotive industry. To glaze the automobiles manufactured in the United States yearly requires from 75 to 80 per cent of the total domestic production of polished plate glass. Virtually all plate glass used by the automotive industry is laminated to make it nonshatterable; the balance is of the Herculite type.

Another important use of the product is for mirrors, which are daily

growing more popular. It is also used to a large extent for the tops of desks, tables, dressers, and so forth, as it not only protects the top from the ravages of everyday usage but also adds a rich beauty of its own.

Present Status of the Industry

Not only has the United States become the outstanding producer of the world in the manufacture of polished plate glass, but this American industry today has facilities to supply all the markets of the world with a quality of plate glass that cannot be excelled anywhere.

23

The Cement Industry

History of Cement

Early applications. Cement is a broad term. If a substance, when mixed with water, hardens into a solid mass by chemical action, it is a cement. There is evidence that the Assyrians and Babylonians used moistened clay or bitumin. These were the cements of that day. It is known that the Egyptians placed clay mortar in the pyramids. The Greeks had a lime composition to cover their walls of unburnt bricks. A Roman scholar, Vitruvius, writing of the glory of the Empire, tells that 2,000 years ago cement was familiar to Roman builders. Typical proofs have descended to us in the concrete foundation of the Forum and in the form marks on the Temple of Julius—a structure free from crack or fracture after 20 centuries. This cement consisted of slaked lime and volcanic ash found near Puzzolani, at the foot of Mount Vesuvius. Its hydraulic properties made it exceedingly valuable in the construction of piers, harbors, and aqueducts. These ancient remains, and also the words of Vitruvius that have come down to us, briefly indicate the history of cement until the eighteenth century.

The origin of hydraulic lime. In 1756, cement became a more closely defined term. John Smeaton, a civil engineer, was employed by the British Government to erect a lighthouse on the sea-swept rocks of Eddystone, in the English Channel. All the knowledge in England up to that time indicated that relatively pure limestone when burned at a low temperature (600 to 1,200 degrees F.) would produce a material capable of slaking with water. This material is known as "common lime." It would not set under water, and so Smeaton experimented with various limestones to find the hydraulic property lost since the beginning of the Christian Era. He finally analyzed and tested an impure limestone high in clay content, and it set under water. Accordingly, the Eddystone Lighthouse was anchored in a foundation made from a new cement, blue Lias lime and Puzzolani (volcanic ash) brought from Civita Vecchia near Rome, Italy. Smeaton's success initiated the widespread adoption of hydraulic lime. He showed that the color and texture of the limestone were not important but that impurities such as clay created the chemical composition necessary to hydraulicity.

Grinding of burned clay, Roman cement. The patent of Joseph Parker, recorded in England in 1796, brought cement still closer to our present understanding of the term. He took so-called "nodules" of clay and burned them with a heat nearly sufficient to vitrify or melt them. The nodules were then ground to a powder mechanically. Mixed with water, this powder formed a mortar or cement stronger than any then known. Parker's method differed from Smeaton's in that the latter burned his raw materials only enough to drive off the carbonic acid gas and then reduced them to powder by slaking with water. The composition of both these cements was about 45 per cent lime to 30 per cent silica and alumina

Parker's, or Roman, cement did not slake but had to be ground to show its hydraulic properties. It was the first commercially successful natural cement With improved methods of manufacture, this product came to be the most popular hydraulic binding material in use until the twentieth century. Owing to the unequal distribution of the raw materials in the earth—lime, silica, and alumina, as contained in argillaceous limestones—natural cement was not a reliable material. Often 20 to 25 per cent of the cement was inert because of the excess of certain proportions. However, the relative simplicity of manufacture soon placed natural cement on the English market as an approved building material.

First cement made in America. Canvas White in 1818, at Fayetteville, Onondaga County, New York, was the first to manufacture cement in America. His activity was inspired by the need for a superior material in constructing the new Erie Canal. The cement rock he discovered at Fayetteville was adapted to natural-cement manufacture. That White's methods came from England we cannot doubt. The cement he offered brought 20 cents a bushel. So successful was this venture that the state purchased his patent for $20,000.00.

The canal systems and cement. The canal systems in their heyday were responsible for the early progress of the cement industry. From New York to Virginia, from Minnesota to Kentucky, cement mills were erected to supply the immediate demand for safe, watertight masonry in canal construction. When a foothold for the industry had thus been gained, the mills turned to the canals as the cheapest and quickest means to transport their products to market. Leaky and roofless barges made it necessary for the cement to be packed in watertight barrels.

Natural cement, despite its variables and irregularity, found little or no lack of activity among buyers. Production increased through the century from 300,000 barrels in the initial 1818 to 1829 period to 8,868,179 barrels in the year of 1899, though at the turn of the century the methods of manufacture were still crude. The raw rock was burned between layers of coal in vertical stone kilns. A good week's output was 150 barrels of cement. Crushers, like coffee mills, broke up the calcined (burned) rocks. Old-fashioned burrs, or sandstones, did the final grinding. The result was natural cement.

Discovery of Portland cement. Joseph Aspdin, an English bricklayer, had in 1824 obtained a patent on an improved cement. He called it "Portland cement" because of its resemblance in color to building stone from the Isle of Portland, a rock like that used in Westminster Abbey His product was distinguished by a high specific gravity and could not be classified as a simple hydraulic lime. It was made by mixing materials not already blended by nature and by burning them at a high temperature. The materials were finely pulverized lime and clay. The important point was that all previous experiments and patents had suggested the development of an artificial hydraulic lime. If in burning pieces became vitrified (hardened to clinker), they were studiously discarded. Unfortunately, although Joseph Aspdin discovered the need for a high kiln temperature and gave to his material the name we all know, he did not arrive at our present material.

Another Englishman, by the name of Frost, introduced a cement in 1822 which came close to Aspdin's later standard. Frost was the first to erect a factory for the manufacture of Portland cement. It was located near London and produced its first cement in 1826. Isaac C. Johnson, a leader in the cement industry of England for many years, claimed to have been the original maker of cement that met British and foreign-government standards, but no one man enjoys complete recognition as the inventor of Portland cement.

Since it was the product of the intense burning of certain rocks, constantly improving methods led gradually to a remarkably high degree of standardized practice. Basically, Portland cement achieved three times the strength of natural cement and could be mixed with a large proportion of sand and gravel without losing its cohesiveness, whereas lime could not be mixed with more than seven times its volume of foreign matter.

Saylor, pioneer American manufacturer. Portland cement was manufactured in the United States for the first time by David O. Saylor. He had been a natural-cement manufacturer in the Lehigh Valley, Pennsylvania. The process by which Saylor burned his raw rock was rewarded with patent protection in 1871. Soon after the new cement was being produced on a commercial scale. One great difficulty arose in the failure of the cement due to the varying quality of raw stock. However, reburning the calcined rock resulted in a clinker which ground into a good Portland cement. Seven years later, in 1878, the product had been marketed to the amount of 28,000 barrels, or only 1 per cent of all other cements. Saylor's cement basically conformed to the following definition:

> Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no addition subsequent to calcination except water and calcined or uncalcined gypsum.

This substance is a composition of approximately 20 per cent silica, 10 per cent alumina plus ferric oxide, 65 per cent lime, and 5 per cent other compounds.

Difficulties in marketing Portland cement. From 1878 to 1897 the Portland-cement industry struggled for its very life. Even considering manufacturing crudities, the product was equal or superior to any cement in the world, but users were skeptical almost to the point of boycotting domestic Portland. Their preference was given to imported Portland, of which 92,000 barrels were consumed in 1878. In 1888 this quantity jumped to 1,835,000 barrels, as compared to 250,000 barrels of domestic Portland; and in 1895, 2,997,395 barrels came into the country, whereas our mills produced less than 1,000,000 barrels. That was the greatest year up to the present time for imported cement.

England, France, Belgium, and Germany were shipping to this side of the Atlantic. As our exports far exceeded our imports, cement came in frequently as ballast on tramp cargo ships The rates were low or "scratched off" entirely. A chain of distribution was built up to handle this cement, utilizing railroad competition to obtain price advantages on the cement shipped to the interior. Foreign cement was established by brand names, sold for less than domestic, and enjoyed the confidence of engineers and builders. Even so, 1897 saw over 50 per cent of American consumption come from American mills. Then came the war with Spain.

The impetus of Government approval. Natural cement had been clinging to a major share of the market up to this time. One barrel of all Portland cements was sold for every 10 of the natural kind. Scientific formulae had been derived with the aid of hammers, cookstoves, and coffee mills. After the processes of manufacture had been determined, the product was not desired, and it was even forced to suffer the ignominy of being marketed under foreign cement labels.

The Government had important fortification work to do during the 1897 to 1899 period and placed its endorsement on domestic Portland cement. The resulting stimulus and prestige almost doubled the production of Portland during these two years. At the turn of the century, natural cement had an annual production of 8,383,519 barrels, Portland cement showed 8,482,000 barrels, and imported cements had only 20 per cent of this figure. Thus the pioneer work of Saylor and his contemporaries was rewarded.

However, much remained to be done, especially in the development of mechanical processes to bring a reduction of labor costs and a more uniform, reliable cement. Europe was paying only one half to one quarter the wages of America. America needed a new procedure for manufacture to offset this handicap, and some of the finest inventive and engineering minds were attracted to the task of determining what this procedure should be.

The problems of the industry in 1900. American dominance in Portland cement really began with the engineering genius which adopted and perfected the rotary kiln between 1890 and 1896. The development of this device meant the standardization of the product in the most important step of manufacture. In many respects the "gamble" was taken out of manufacture; quality was assured. The buyer, no matter what

his practice had formerly been, could not deny the excellence of this domestic "rotary-kiln" cement. Yet a product that had sold at $9.00 a barrel and in 1890 was still over $2.00 per barrel could not be used in every type of construction, no matter how good it was. The problems of the industry were threefold: first, the cement had to be improved and made more uniform; second, the price had to be reduced; and third, the product needed research and promotional energy to make its applications both wide and successful.

Economic Importance of the Cement Industry

Production. Wage earners in the cement industry in 1928 were twice as many as in 1904, but production was eight times as great in 1928. Here is evidence of shrewd application of sound methods in management during the early-growth stages of the industry. In 1928, 156 plants in 33 states produced 175,838,000 barrels. In 1938, the ratio of output to employees declined somewhat from 1928, with 151 plants producing 105,357,000 barrels. During that decade, this was a decrease of 40 per cent in production as against a decrease of 33 per cent in wage earners. Two contributing factors were the need for retention of certain fixed labor, regardless of production, and the shortening of the workday, necessitating more men in the plant. The production of the United States was more than 40 per cent of the entire world output. Germany, France, England, and Belgium were the other leading cement producers. All of America's production except for 550,000 barrels was consumed in the United States. Imports for the year were 1,715,000 barrels.

The tariff on cement. Since the First World War, European countries have not only captured most of our export business but, because of their favorable prices, have also found a market in this country.

Cement was the beneficiary of a protective tariff until 1913 Again in 1930 a tariff was applied of 6 cents per 100 pounds, with the result that imports were cut in half, while exports nearly held their own during 1930 in the face of curtailed construction the world over. The reason for the resumption of the tariff can be traced to the fact that the United States in 1928, an unusually good building year, operated its cement plants at only 74 per cent of capacity, yet found itself the second largest importer of cement.

Further curtailment of the construction industry in the 12 years after 1928 forced the operating rate of these plants to new lows of between 28 per cent and 55 per cent of capacity, with improvement and higher rates during the last 3 years of the period Foreign countries whose cement plants use cheap labor have consistently taken advantage of low shipping rates to unload their product on both Americas, thus cutting off our export trade as well as aggravating our own labor problem and upsetting cement prices in the seaboard cities. Cheap shipping rates permit certain foreign countries to ship a product to America at less than the American manufacturer has to pay to reach the same market.

In 1939, there were approximately 95 major operating companies, with a total invested capital of nearly $650,000,000.00. The value of output in 1939 was $1.47 per barrel (national mill average) on 122,651,000 barrels. These figures are fairly typical of the cement industry within the past 10 years During the mid-1930's, production and prices were severely depressed because of the general fall in construction activities; however, since 1937 production and mill averages have been advancing slowly. Though there have been improvements, the production for 1939—the highest recorded since 1931—was 31 per cent less than the all-time high of 1928, and the price was 15 per cent lower than in 1928. Wage earners in 1939, over 26,000 in number, received more than $34,000,000.00, and the total payroll was nearly $50,000,000.00. The cement industry consistently holds the position of the third largest rail shipper of manufactured products in the country, second only to oil and steel. It is one of the largest users of coal, and ranks near the top in electricity consumption.

Major classes of cement usage. The United States is the leading nation in per capita consumption of cement. Of this, 30 per cent is found in structural concrete—buildings of all types, bridges, dams, water-power projects, storage tanks, reservoirs, and river- and harborwork. Paving and highway take up 24 per cent. Concrete products, including block, pipe, tile, and specialties, consume 10 per cent. Conservation requires 9 per cent and farms 4 per cent. Small homes and other diversified uses account for the remaining 23 per cent of production. From skyscrapers to sidewalks, from stadia to silos, wherever modern building is in process, one will find cement.

Raw Materials

A uniform cement naturally demands uniform raw material. This fact accounts for the location of cement mills.

It has been said that cement is a mixture of argillaceous and calcareous materials. Therefore, where these requisites abound, cement is made, provided that a ready market for the product is conveniently close at hand. An article of the weight, bulk, and cheapness of cement can be shipped by railroad only to the limits of the competing mill's radius. A New York City dealer, for example, buys from mills near Albany and from those in the Lehigh Valley, since mills in those sections are able to undersell any other districts, or rather to make a profit where the "outside" mills would suffer a loss.

Classification of materials. The argillaceous materials are clay, shale, slate, blast-furnace slag, and cement rock. In these are found silica, alumina, and iron oxide in large proportions.

The calcareous materials are limestone, marl, chalk, marine shells, and alkali waste. In these are found lime (combined with carbon dioxide as calcium carbonate), magnesia, and minor impurities. It is common practice to use one calcareous and one argillaceous material in manufacture, because only rarely is the correct composition found in any

single deposit. About 30 per cent of cement is made from limestone and cement rock, since this mixture is the most popular in the Lehigh Valley district. Approximately 57 per cent is made from limestone and clay or shale, a combination widely distributed. A slag and limestone mixture is used for 10 per cent, and marl and clay for about 3 per cent.

Limestone in its pure form is the mineral calcite. When carbonate of magnesia reaches 45 per cent in limestone the rock is known as "dolomite." For cement, limestone should not have over 7 per cent carbonate of magnesia (5 per cent in the finished cement). Lime in the raw stock can run as high as 75 per cent. The composition of Portland cement is as follows:

Ingredient	*Per Cent*
Lime	60-65 %
Silica	19-25
Alumina	5-9
Iron oxide	2.5-3.5
Gypsum	2.0
Miscellaneous ingredients	0-5.0

Using the 75 per cent lime as a basis, the cement manufacturer adds to his cement rock either purer limestone (if below 75 per cent) or clay or low-in-lime cement rock (if above 75 per cent) to maintain the required proportion.

Cement rock is the name given to Trenton limestone of the lower Silurian Age. It lies between Hudson shales and Kittatinny magnesium limestone. A ton of cement rock and limestone must be quarried to make 3 barrels of cement (1,128 pounds).

Marl is a more or less pure carbonate of lime. It is found on the bottom or banks of extinct lakes and is formed by the precipitation of calcium carbonate from the water by algae or water plants. Marl has to be dried, as it usually contains about 50 per cent water

Clay in its purest form consists of kaolin, a hydrated silica of alumina, but more commonly is made up of a mixture of kaolin and finely eroded materials, such as quartz, feldspar, and mica. It is formed by the disintegration of rocks containing minerals made up largely of alumina and silica. Silica should predominate by two and a half to four times in clay used for cement manufacture.

Shale is simply solidified clay. It is preferable to clay because it can be more easily handled and requires less drying. Shale is most frequently used with limestone, for both are dry. Clay is used with marl for the opposite reasons, namely, that both are wet and do not segregate.

Slag is the product of blast furnaces working on pure ores only. It is granulated by cooling suddenly with water and is then dried, ground, and mixed with ground limestone. Slag is a comparatively new ingredient in cement manufacture and is being used by plants in the ore centers of Indiana, Pennsylvania, and Minnesota. The Ford plant in Detroit has also adopted slag as a raw material.

Gypsum is hydrated sulphate of lime. Either calcined or in its native

state, it is added to cement to slow the set. About 8 pounds are required for every barrel of cement.

The Location of Cement Mills

Cement mills are located at the source of supply for the raw materials. (See Figure 1.) This is, of course, the reason for the position of the Lehigh Valley district as the greatest center of cement production in the world. The Lehigh Valley district, comprising the eastern counties of Pennsylvania together with that part of New Jersey adjacent to Easton, Pennsylvania, has been the leading producer from the day of

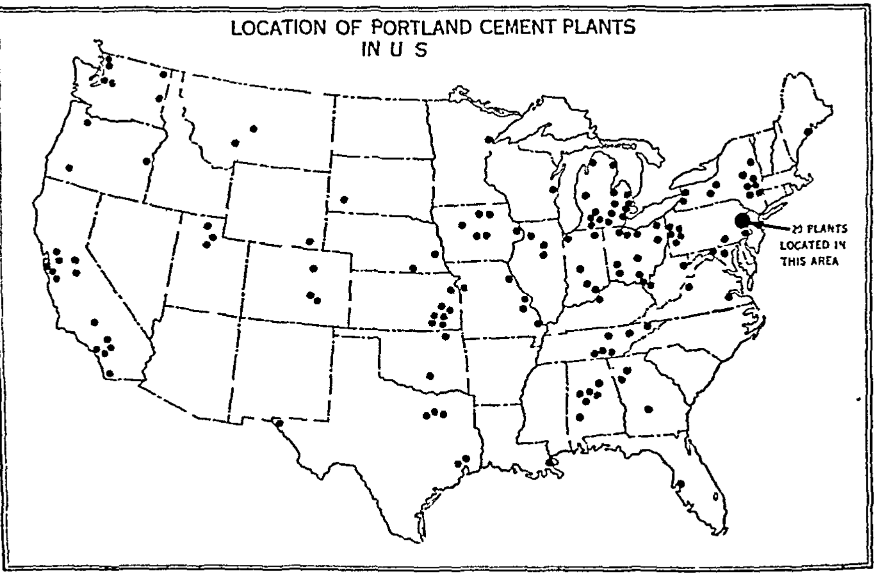


Fig. 1.

Saylor. Nearly a quarter of the country's output comes from the 20 or more mills in this restricted area. California, Michigan, New York, Ohio, Illinois, and Texas are the other important centers of manufacture. However, this growth would not have been possible had it not been for the proximity of the New England, New York, and Pennsylvania markets. Cheap coal and labor have also been important contributing factors to the success of this territory.

Manufacture of Portland Cement

The necessity of chemical control. Even if the raw materials are of satisfactory quality, it is a difficult task to mix them accurately. A quarry's product does not run exactly uniform. It is necessary to make chemical tests before the material can be touched, and these tests must

be continued through every step of manufacture. Night and day in the cement plant the laboratory is busy. No material can be used, not a motor can turn until the chemist gives his approval. To be sure, there are definite mechanical aids to facilitate this control of the product from start to finish. The chemist works from formulae and applies them to his materials, so he must have a record of everything—every hour of the day. The American Society for Testing Materials has specifications which cover the physical properties of cement, and these are adhered to by all manufacturers. But a plant cannot risk an inferior product that will be discovered only after it is made and ready to be sold Mechanical processes are standardized for treating the various combinations of raw materials. Only the laboratory can fix these combinations and so protect the plant and its product.

Influence of materials on basic processes. Of the raw materials, limestone, cement rock, and shale are quarried. (See Figure 2). Clay

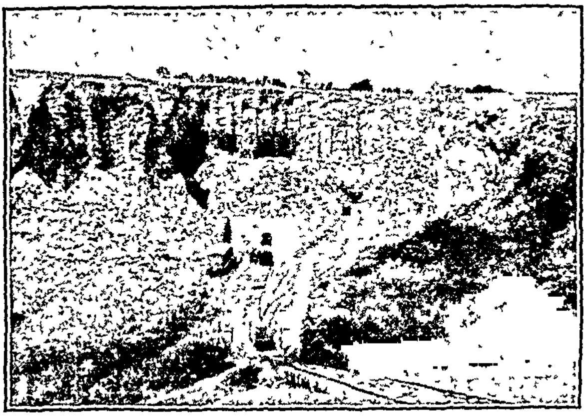


Fig. 2 Quarrying. In this type of quarry cables operate the cars after they are loaded by steam shovels.

is dug from pits. Marl is dredged, often from under water. Mining is adopted only where the overburden of undesirable material is too thick to be stripped off. Stripping is sometimes necessary if the impurities are great, as their presence may complicate the regulation of the necessary mix; or, in the case of clay, they may make necessary the addition of considerable expensive limestone. Cement rock is blasted; the whole vertical face of the quarry is brought down at once to a depth of 16 to 20 feet. Steam shovels load the broken rock on to small skip cars that are pulled out by an electric incline-cable hoist, if the floor of the quarry is deep enough to require it. Electric locomotives then take the skips directly to the crusher. Cement rock and limestone may contain only 5 per cent moisture. Marl, on the other hand, may contain from 50 to 60 per cent. This material is handled differently, being put into barges from the dredge and thence on to a belt conveyor for transporta-

tion to the mill. It may even be mixed to a uniform consistency in revolving steel cylinders and pumped to the mill.

The wet and the dry processes. It is possible to see now that there are two well-defined classes of raw materials, wet and dry. Similarly, there are two processes of manufacture, the "wet" and the "dry." Whenever clay or marl is used, the wet process is followed. Cement rock, on the other hand, calls for the dry method. The latter method is of American origin. The rock must be crushed, dried, ground, and burned. The initial step is expensive, but the burning is obviously less expensive, since it treats a dry, powderlike substance. In the wet process the material is crushed, mixed with water and other essential ingredients,

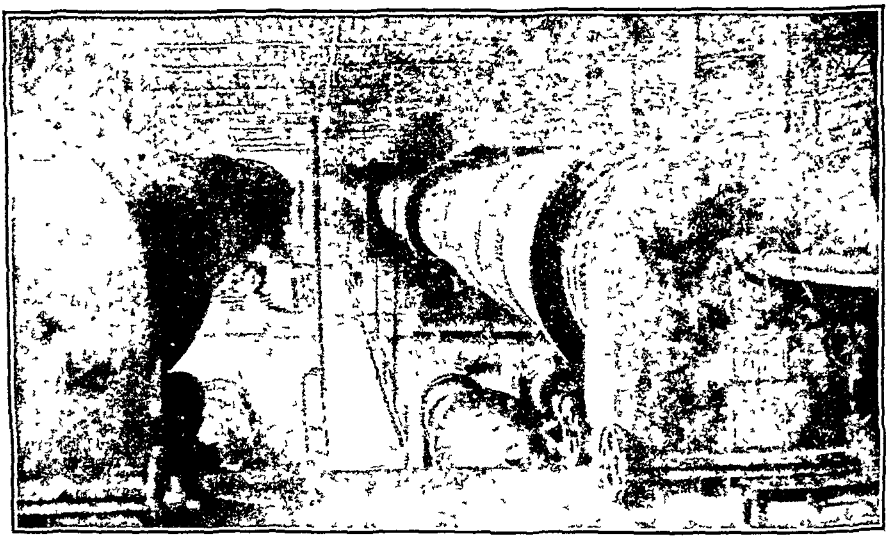


Fig. 3. Rotary kilns.

ground, and burned wet in the kilns. It is the consistency of thin mud when ready for burning (containing 35 to 40 per cent water).

It is claimed for the wet process that chemical control is easier because the contents of two or more "correcting" tanks can be mixed as required just prior to burning. In the dry process, while the ground material is stored and then remixed before burning, much of the success depends on the chemist's good judgment in making his corrections from earlier readings.

Crushing the raw stock. A plant using the dry process usually crushes its raw stocks separately, stores them in separate bins, and mixes them by a pair of automatic electric scales just before grinding They are in some cases ground separately and then mixed after analysis. In the wet process the materials are crushed separately and stored The clay is worked into a thin solution in a wash mill and the limestone is added at the grinding mill. Tanks or houses with several divisions of bins are customarily used for storage. The material is drawn out from

the pretested divisions through spouts at the bottom on to belt or screw conveyors.

The crushing of rock in the dry process is managed by gyratory crushers, jaw crushers, roll crushers, and hammer mills. More than one set is often necessary to reduce the rock to a maximum of about 1 inch in diameter. Crushers are capable of reducing an 8-ton rock at one bite.

Drying raw materials. Drying is next necessary to remove most of the 5 per cent moisture. Rotary dryers are now used, measuring 5 to 8 feet in diameter and 50 to 80 feet long. (See Figure 3.) They are direct-fired in the majority of plants. Oil or powdered coal is the heating agent. The cylinders revolve on bearings and are tilted to carry the material from the coal end to the combustion end. Clay sometimes balls

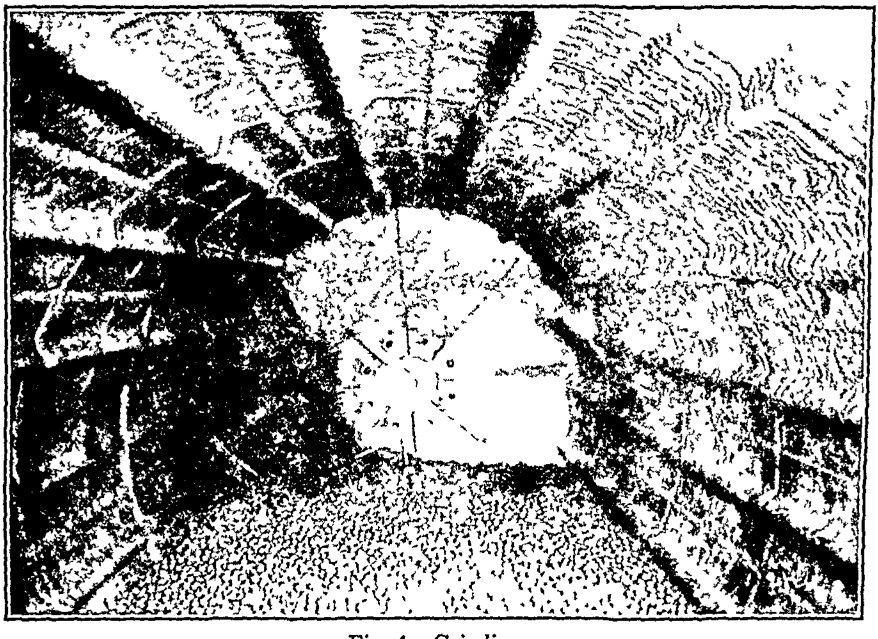


Fig. 4. Grinding.

up—that is, it bakes on the outside and remains wet on the inside. In such cases it is necessary to crush and redry it

Comparative advantages of the two processes. The wet process originated with the use in cement manufacture of the soft chalk found in England and north Germany. Beside offering economies in grinding and drying, the material is easier to handle and there is less dust. On the other hand, more fuel is needed for the kilns, more coal must be ground, the kiln capacity must be greater, and some power is needed to agitate the slurry.

Grinding raw stock. One of the two most important steps in manufacture is the same in both processes. This is the grinding. It is done by what is known as "Compeb mills." (See Figure 4.) These are steel

tubes approximately 7 to 10 feet in diameter by 22 to 40 feet long. The inside is lined with ribbed plates. A division marks the interior 5 to 6 feet from the feed end. It is in the form of a grid screen that lets the properly ground material into the next section. Some 20,000 pounds of steel balls up to 5 inches in diameter occupy the first section; about 70,000 pounds of smaller balls up to 1¼ inches in diameter are in the second. The material is literally smashed to bits by the action of these balls. The mills revolve rapidly on shaft drives. Their product is finer than flour. As much as 97 per cent of it will pass through a sieve with 10,000 openings to the square inch. It is popularly known as "chalk" in the dry process and "slurry" in the wet process. It takes 620 pounds of chalk to make a barrel of cement. Both the slurry and chalk are stored before entering the kilns in order to permit them to be mixed thoroughly and tested in the laboratory for final corrections and also in order to keep the kilns supplied if any emergency should require shutting down the department which handles the raw material of the mill. The slurry is put in basins and agitated constantly prior to burning.

Burning the ground material. The next process is the most fascinating of all. Ground rock was burned in upright dome kilns to make the first Portland cement. Alternating layers of rock and fuel were placed in the kiln, and it was a week before the charge of about 100 barrels was burned. The modern rotary kiln can deliver over 1,000 barrels in a day. F. Ransome received the patent for this type of kiln in England in 1873. American adaptations of this style were about 60 feet long until Thomas A. Edison patented a kiln 150 feet long in 1909. Lengths up to 500 feet are now in use. Manufacturers were afraid that elongated steel tubes would warp if lengthened until Edison proved his case by practical demonstration. The increased size meant far greater capacity, uniformity, and economy.

The kiln construction and function. The modern kiln is a sheet steel tube 6 to 12 feet in diameter and 110 to 500 feet long. The tube is supported on steel tires or rings and is driven by girt gear. The material enters one end of the tube, where the temperature is perhaps 400 degrees F. It is carried along the passage lined with fire brick by the slow revolving of the tube and by its slight pitch (18 inches in 150 feet). Shooting into the kiln for perhaps 30 feet of its length from the opposite end is a jet of flame. This is caused by pulverized coal, oil, or gas burning under pressure. The temperature created goes up to 2,800 degrees F., high enough to melt gold, silver, or steel. It turns the fine mixture into clinker sufficiently hard to scratch plate glass. A moderate-sized kiln 9 feet by 150 feet can produce 825 barrels of clinker in a day and uses over 40 tons of coal or 8,250 gallons of oil in doing it. The kiln is a 24-hour, 7-day-week worker, because of the expense of starting it when allowed to idle and cool. With the wet process, it is estimated that only 60 to 70 per cent of dry-process production is reached in the kiln.

Clinker, product of the kiln. After the use of the kiln, there is no difference between the wet and dry processes. The clinker is about the size of a marble. It is cooled by water and sometimes by rotary

coolers. Clinker is stored where most convenient. Reserve stocks can be kept out of doors without injury. As it is needed, the clinker is weighed by electric scales and the prescribed quantity of gypsum added automatically. Mills similar in most cases to the Compeb type reduce the clinker and gypsum to the ultimate product, Portland cement. The cement particles are so fine that 94 per cent will pass through a sieve with 40,000 openings to the square inch. Large stock houses that look like silos or tanks receive the cement, and it is drawn out as required for immediate bagging and shipping.

Packing Portland cement. Most cement for domestic consumption is packed in bags, although bulk car shipments are also required. The latter are economical when the cement is to be used by central mixing plants and no subsequent handling of any kind will be necessary. A bag of Portland cement weighs 94 pounds. The unit of sale is the barrel, which contains 4 bags.

The Bates machine has been adopted in nearly all plants for bagging. There are 3 spouts to the machine operated by one man. He inserts a spout into a hole in the bottom corner of the bag The bag is filled and the supply is automatically cut off at 94 pounds. The bags of course are wire-tied at the top before the filling operation. A 3-tube machine delivers 1,000 to 1,500 barrels per 10-hour day, or enough to fill 5 to 7 freight cars. Shipments are made in either cloth or paper sacks. If the former are desired, the customer pays 40 cents a barrel (10 cents a sack), to be rebated when he returns the bags. It is estimated that over 65,000,000 cloth sacks are lost or destroyed each year. Two trips a year are average for a cement sack. Between trips it must be cleaned and repaired by the mill. There is also a charge of 15 cents a barrel for paper bags, which is not rebated. Nevertheless, the convenience of paper bags has forced their promotion, until nearly as much cement is shipped in them as in cloth.

The power behind the mill. Until a few years ago, the boilers in a cement plant were regular, direct-fired models. Then it was discovered that the waste heat from the kilns might be utilized. Now waste kiln heat generates steam to drive the turboelectric generators. The turbines operate every unit in the plant at a 50 per cent cut in coal consumption. In addition, the waste gases heat the feed water for the boilers to 200 degrees F. Today it takes 130 pounds of coal to make a barrel of cement; a few years ago over 200 pounds were used. At that time all equipment in a cement plant operated from a belt-driven pulley, connected to a common line shaft. Since it does away with engines entirely, the individual electric motor drive is best today. There is no shafting, no line friction; the plant can be shut down where and when desired; the operation is smooth, continuous, and uniform throughout. Direct-connected motors are used for kilns, crushers, grinding on raw and finishing ends, conveyors, and so forth. A 1,000-horsepower motor is not rare; a 60-inch belt is common. The power installation for a single large cement plant (2,500,000 barrels annual capacity) produces

enough electricity to supply a city of 150,000 with power and light. Yet this plant might employ less than 500 men

Engineers have been bending constant effort since the inception of the industry to gain more exact control of the extremes that are employed in the manufacture of cement. Since it is necessary to work up such great power, force, and heat, and to handle such very fine and minute particles of ground materials, the most direct attacks on the loss of efficiency in the mill have been made along the lines of securing the greatest heat per unit of fuel. Once the heat has done a job, it cannot be allowed to escape through the stack, for the loss would be prohibitive to the continued operation of the plant. The idea is to recuperate every unit of heat possible and reëmploy it in another task. Steady improvements have been made in fuel burning, kiln insulation, and heat-recuperating devices. Another advance has been the growing use of dust-collector systems to catch the very fine particles of ground materials before they escape from the mill.

Care of wage earners. For the laborers in a cement plant, all facilities necessary to assure bodily cleanliness are maintained. A cement plant is dusty; the dust is particularly difficult to control in dry-process plants, and its lime content makes it especially unpleasant. Screens, ventilators, and enclosed construction are helpful in reducing the spread of dust. But after a day in the average mill, any person is entitled to a shower and change of clothing. Modern provision is made in all plants for the wage earner's care, whether in sickness or in health, and in many cases there is organized supervision of the employees by a company official. Accidents have been reduced by education and protective devices until as many as 20 plants have gone through a year without a single serious injury.

Cement and Concrete

The secret of cement's value. In all, there are over 80 operations in the production of Portland cement. To carry them out the largest revolving machinery in all industry is called into play. Raw materials are burned until melted to a pastelike form under the kiln heat, certain gases are driven off, and a new composition is formed from the elements remaining. When ground, this substance becomes capable of a great affinity for water. The chemical reaction is called "hydration." The cement and water form a paste which coats every particle in the mixture of sand and stone, hardens, and renders the entire mass rocklike in character. Thus we have concrete, the indispensable ingredient of which is Portland cement.

Concrete. The water-cement ratio of proportioning is an integral part of modern specifications for concrete work. This ratio calls for the minimum amount of water that will make the mixture workable. For example, 1 cubic yard of concrete floor will require 6 sacks (6 cubic feet) of cement, 38 gallons of water (6⅓ gallons per sack of cement), 12 cubic feet of sand, and 18 cubic feet of stone. This is what is known as a

"1:2:3 mix." Concrete must be cured after placing, and warm, moist conditions are desirable to complete the chemical action.

Marketing cement. The problem of transporting cement from the plant has been mentioned. About 200 barrels, or 800 bags, are loaded to a car. The medium of sale is the dealer in building materials. He has facilities for financing, storage, and delivery. Cement is sold direct to him, although it may be shipped to the contractor to avoid needless handling. Manufacturers make contacts with all building interests which influence purchases. Likewise the dealer makes an independent selling effort.

The dealer does not ordinarily carry large stocks of cement. Therefore all substantial orders are filled by the cement mill, which must be in a position to ship within a few hours. As the mill does not carry stocks in bags, this means that, on each order, sacks must be filled and cars loaded. The price of cement is based on a mill-net figure of, let us say, $1.60 a barrel. The dealer pays this figure plus the 40 cents per barrel for cloth bags, on which he is entitled to a rebate, or 15 cents per barrel for paper bags. To this is added the freight charge, which may run as high as 30 per cent of the mill net. The dealer's price, then, is, for example, $2.48, the mill net, the cloth bags, and the freight charge making up the total. The dealer receives usually 10 cents per barrel and an additional cash discount as his share in the transaction. If a manufacturer is situated less advantageously, thus making his freight rate higher, he will take business at the $2.48 figure and sacrifice his own mill net. A dealer may represent several manufacturers to satisfy the preferences of his customers for particular brands. This representation is limited, however, to companies that, because of their mill locations, can sell at a profit in the dealer's territory.

Developing uses for cement and concrete. There is a never-ceasing search for consumption outlets for Portland cement. The future of the product depends on the same research and development work that has characterized the industry in the past. Reinforced concrete is without equal for durable, rigid construction. Steel rod and wire mesh, when interlaced with it scientifically, form a mass highly resistant to side stresses, as is evident in concrete floors and highways. There is an indication of the success of steel-frame houses in recent tests, and Portland cement stucco forms the ideal, protective, and decorative surface for this type of construction; it is fireproof, waterproof, and demands the very minimum of upkeep. Stucco is a mixture of Portland cement, sand, and water. The coarser aggregate, crushed stone, is either omitted or is present only in very small quantity.

Admixtures, such as calcium chloride, are now frequently used in the concrete mix to quicken the hardening. The clinker is burned twice to produce a cement of similar rapid hardening quality. In highway construction or wherever the concrete must be ready for use in a few hours—strong, firm, and wear-resistant—such preparations hasten the usefulness of the work. Labor and time economies are also effected.

Concrete is neat, clean, and almost imperishable. These and other

qualities recommend cement for the most lasting of building projects. Cement is made into precast units, known as "concrete products," of endless application. Block, tile, singles, pipe, and ornamental stone are the more important of these products. Some reproductions in concrete of natural stone are so faithful that architects specify them from choice. The variety of possible shades and textures meets the artistic demand; the ruggedness and strength fills the practical requirement. Architect and farmer alike have accepted Portland-cement concrete for as different reasons as the versatility of cement suggests.

This common acceptance of Portland cement has fostered a new trend in the industry. Up to a few years ago, all cement conformed to one or two standards requiring uniform specifications. But in recent years, requirements for various types of projects have demanded that the cement used should contain certain chemical and physical characteristics. Thus, in addition to regular Portland cement, there are now a number of other types, as High Early Strength, Low-Heat, Oil-Well, Sulphate-Resistant, and Masonry cement. Of course, in specifying any of these types, the engineers and architects insist on samples being submitted to one of the numerous testing laboratories to assure them that the cement will meet the specifications they desire. Once the cement has met the requirements, it is necessary for the manufacturer to set aside a certain quantity for the particular job while he goes on to produce a cement to meet another test. This has caused the manufacturers great inconvenience and expense, as they are unable to utilize their full storage capacity. Where a storage bin may hold 5,000 barrels of cement, it may be necessary to assign this bin to hold 3,000 barrels of a tested cement. Nor may any other cement be put into this bin until it has been emptied, which may take 2 weeks to a month, depending on the progress made on the construction.

Cement, a leader in construction. Already concrete dominates the engineering and structural successes of the country. In 1879, the stone foundations of the Washington Monument in Washington, D. C., were replaced by a concrete footing, 16,000 square feet in area. This was one of the earliest and best-known applications of Portland cement. In 1929, the tallest reinforced concrete building in America was the Master Printers' building in New York City, 299 feet high. The size of bridges has been increased to ever greater dimensions. The New York Triboro Bridge was a $60,000,000.00 project. The Golden Gate Bridge in San Francisco required towers 746 feet high, and the deck of the bridge attained a height of 200 feet at the highest point over the water. The Bay Bridge in San Francisco Bay has a length of over 37,000 feet. The two greatest concrete stadia are at Los Angeles, California, with a seating capacity of 75,000 or more, and at Soldiers Field, Chicago, with room for 100,000.

Famous dams made of concrete on this continent are only exceeded in their individual sizes by the vast comprehensiveness of the entire dam-building program that has been carried on in America since 1928. Among the greater dams are the Grand Coulee Dam, with 11,250,000

cubic yards of concrete alone; the Boulder Dam, over 600 feet high; and the Shasta Dam, 560 feet high. So great is the amount of material and machinery used in the construction of these projects that it is often advisable to build factories at the site of the project. Another type of construction that has progressed rapidly is the tube for carrying automobiles, trains, and water. In tunnel construction, the City of New York alone has 6 tubes under the Hudson River, 22 under the East River, 3 under the city proper, 3 under the Harlem River, and 4 vehicular tubes, not to mention countless miles of aqueduct and smaller tunnels. The Cascade Tunnel in the State of Washington, 7.78 miles long, is one of the longest railroad tunnels in this country.

In America, there are over 96,000 miles of concrete highway of all kinds. A concrete road costs about $25,000.00 a mile to construct, of which 52 per cent is paid out for labor. Though this initial cost is greater than the cost of any other hard-surface roads, the maintenance cost for concrete is only 25 per cent of what it is for other hard surfaces. Less tire wear, lower gas consumption, and greater traction are advantages of concrete highways, aside from their cleanliness and durability.

These are some of the more notable examples of concrete application in the past. In the future, there will be further developments of these achievements. There will be concrete steel houses, built according to standardized forms to cut building costs. Airports have already applied concrete to runways and hangar aprons, necessities for successful bad-weather operation. There will be more express highways of the Pennsylvania Turnpike type, 12 lanes wide, and built to accommodate a speed of 100 miles per hour. Surely there will be other outlets, impossible to foresee now, just as the present immense projects were hard to visualize even 10 years ago. Though the innovations in the applications of cement are obscure until conceived in the mind of man, it is certain that the future will bring developments along the lines of present uses but of greater size—greater dams, greater bridges, larger road systems, and the like. All will help to contribute to the second cycle of growth of this industry.

The Portland cement plants in the United States today, producing at capacity, would require in a year enough 94-pound sacks to keep you walking if you cared to count them all, one after another, 340,000 miles. If you preferred to count loaded freight cars, there would be a mere 1,250,000 of them.

24

The Chemical Industry[1]

The Chemical Industry—The Chemical Process Industries

Born of chemistry and economics, the chemical industry is not what a large part of the public thinks it is. It does not mean fireworks, glue, writing ink, matches, or perfume—although all of these are essentially chemical in nature. Rather it is something much larger, much broader in its industrial significance, though less evident to the public eye. Only an insignificant part of the total output of the industry ever reaches the ultimate consumer in anything like the form in which it emerged from the chemical plant.

An exact definition of the term "chemical industry" is something for which those who have occasion to write and talk about the industry have been looking for many years. For want of something better we could say that the chemical industry is any industry wherein chemical rather than physical change of materials is involved, where the arrangement of atoms and molecules is altered instead of, or as well as, shape, appearance, and texture of the material. For the purposes of this chapter, however, and in the light of the generally thought-of meaning of the term, this definition of chemical industry is still too broad inasmuch as it allows inclusion of such industries as soap, cosmetics, and paints and varnishes which are not strictly chemical industries. These latter industries involve chemical changes of materials, but to distinguish them from strictly chemical industries they are generally referred to as the chemical process industries. In addition to those mentioned above, they include such well-known industries as pulp and paper, petroleum refining, rubber, ceramics, textile processing, cement, glass, and sugar—a group which represents almost one fifth of all the manufacturing enterprise in the United States.

The primary distinction between the chemical process industries and

[1] Much of the material in this chapter has been taken from the September, 1939, "Facts and Figures" issue of *Chemical and Metallurgical Engineering* (New York: McGraw-Hill Book Company, Inc.). Acknowledgment is also made for extracts from *Economics of Chemical Industries*, by E. H. Hempel (New York: John Wiley & Sons, Inc.), and the original chapter on the chemical industry by Albert H. Hooker contained in the first edition of this book

the strictly chemical industry lies in the extent to which chemical change is involved in the operations of the industry. In the case of the process industries chemical changes are usually involved only in the refining, purifying, or other "processing" of the raw material, the chemical structure of the material itself remaining unaltered. Gasoline and lubricating oils, for example, are chemically the same after refining as they were when they existed as a part of the complicated mixture that is crude petroleum. Chemical changes, however, were involved in liberating and purifying them. Likewise, in the making of sugar from cane and beets the sugar remains unchanged chemically but chemical methods are involved in the removal of impurities from the raw juice. Strictly chemical industry on the other hand is concerned with the manufacture of products wherein the raw material itself undergoes chemical change and a new product emerges which is entirely different in its chemical characteristics. Examples are the manufacture of sulphuric acid from sulphur, and chlorine and caustic soda from common salt.

What might be called a secondary distinction between the process industries and the chemical industry is the type of market served by each. In general the process industries sell their products to the public, the ultimate consumer, whereas the products of chemical industry in the main are such that they are of value only to other industries, and their market is largely an industrial one. The chemical process industries, in fact, are among the best customers of the chemical industry.

Strictly chemical industry is in general what is meant by the term "chemical industry" today. The distinctions mentioned between it and the "chemical process industries" are not ironclad, and in fact there are several outstanding exceptions, but until some more distinct classification is evolved they will have to suffice. Henceforth in this chapter we shall deal with "chemical industry" only.

Foundations of the Industry

One of the characteristics of the chemical industry is its comparative youth, for while it had its beginnings during the Industrial Revolution, its progress was slow and it did not achieve the rank of a major industry until after the First World War. It has been said that chemical industry dates *chemically* from LeBlanc's discovery of his soda-ash process in 1791 and *industrially* from the First World War.

Early activities involving chemistry date back to the manufacture of white lead by the Greeks, of gunpowder and porcelain by the Chinese, of glass by the Phoenecians, but these can hardly be called the beginnings of chemical industry since they were carried out entirely by rule of thumb, and chemistry as a science was nonexistent.

The LeBlanc soda-ash process. During the Napoleonic Wars, France was forced to develop her own alkali industry since the natural soda ash obtained from Spain was cut off. A prize was offered for the best process, which was discovered by LeBlanc in 1791. He produced soda ash from salt, sulphuric acid, and limestone. A small plant was

built in France, but the process was developed to a much greater extent in England, where raw materials were more abundant. In fact, the LeBlanc plants in England, with their correlated products of sulphuric, muriatic, and nitric acids, soda ash, caustic soda, bicarbonate of soda, salt cake, Glauber's salts, alum, and bleaching powder, dominated not only the English market but the world market as well, with Europe, America, China, and India all looking to England for supplies from this newly developed chemical industry.

LeBlanc is generally credited with being the first person to carry to successful fruition a deliberate, planned attempt to make out of one or more chemical products another that is chemically different, keeping in mind not only the product desired but the economics of the process as well. This, in essence, remains the aim of the chemical industry today: to produce new products and better products economically.

The Solvay process. As chemistry advanced, the Solvay brothers in Belgium developed a new method of producing soda ash of greater purity without the use of acid For this process the only raw materials needed were coal, limestone, and salt, and the finished products were soda ash and calcium chloride. Solvay plants spread rapidly in England, Germany, and America. It was a black day indeed for the proud British alkali business.

About this time, however, there developed a shortage in the supply of bleaching powder, a product made from the waste chlorine gas obtained from the LeBlanc process. Bleaching powder prices mounted higher and higher until a balancing point was reached, and soda ash by the LeBlanc process, together with bleaching powder, could be made and sold at a profit in competition with Solvay soda ash. Thus chlorine, which previously had been considered a waste product, became the salvation of a portion of the industry. In the chemical industry today, every new process is evaluated on the basis of the market value of *all* the products obtained from it, not just those of immediate interest.

Electrolytic caustic soda. Later another revolutionary change took place in alkali manufacture, the backbone of the early chemical industry. With the availability of commercial electricity, a process for the economical production of caustic soda and chlorine by the electrolysis of salt brine was developed. Both the electrolytic and Solvay processes are used by the alkali industry today.

Coal-tar chemicals. In 1856, Perkin of England produced aniline from coal tar, a sticky black substance for which no use was then known. In trying to synthesize quinine from this, Perkin succeeded in obtaining only a black liquid that looked as hopeless as the tar itself. The liquid turned out to be a solution of mauve, however, the first synthetic dye. It was thus that the synthetic-dye industry—in fact, the entire great coal-tar chemicals industry, which now includes medicinals, perfumes, artificial flavorings, artificial resins, insecticides, and a number of industrial chemicals—got under way.

The Frasch process. Though not a chemical development itself, the Frasch method of mining sulphur played a significant part in the devel-

opment of the chemical industry, particularly in America, because it made available unlimited supplies of cheap sulphuric acid. Sulphuric acid has often been called the most essential chemical in industry, and this is especially noteworthy in view of the fact that from one third to one half of all the sulphuric acid produced never gets outside of the chemical industry itself. It is the chemical used in greatest volume in the production of other chemical products.

Prior to 1890, practically all sulphur for making sulphuric acid came from Sicily, and the price became almost prohibitive before Frasch developed his simple method of reaching the vast quicksand-covered deposits in Louisiana. By sinking three concentric pipes down to the sulphur beds, he was able to send hot water through one to melt the sulphur and compressed air through the second to force the molten sulphur up through the third. With the new cheap sulphur, sulphuric acid production bounded ahead, carrying the rest of the industry with it.

Growth of the Chemical Industry in America

Early beginnings. The first chemical industry worthy of note in the United States was the production of potash from wood ashes. In colonial times, taxes to England were paid in this commodity. This was the beginning of an alkali industry in the United States. Potassium ferrocyanide and ferricyanide were manufactured in the early days in New England. The equipment consisted of old iron kettles originally used for trying out oils on the whaling vessels. Sulphuric acid was produced by the burning of pyrites which was imported from Spain and the burning of sulphur from Sicily.

Acetic acid, acetate of lime, and wood alcohol were all produced by the distillation of wood. This industry naturally arose because of the availability of hardwoods and the high excise tax on ethyl alcohol, which forced the use of wood alcohol for solvent purposes. The industry also yielded charcoal, tar, and crude pyroligneous acid, which was treated with lime to give methyl alcohol and acetate of lime, a major export in the chemical field.

The manufacture of white lead as a pigment for paint was also an early chemical industry. The manufacture of "Dutch-process" white lead was started in Philadelphia about 1815. Acetic acid and lead sheets or "buckles" were the important raw materials; thus there was another reason for the production of acetic acid. (See Chapter 25, on "The Paint, Varnish, and Lacquer Industry.")

Rapid strides made—important discoveries. The years from 1885 to 1900 saw much development in the industry. Calcium carbide was being experimented with at Spray, North Carolina, by Willson. Hall was developing electrolytic aluminum at Pittsburgh. Acheson was experimenting with a small electric furnace in Monongahela City, Pennsylvania, where he first produced carborundum from clay and powdered coke; this was in 1891. In 1895, electric power was developed at Niagara Falls. In that same year Hall, Acheson, and Willson came to Niagara

Falls to take advantage of this development. Electrolytic aluminum and carborundum had heretofore been commercial failures, but the cheap power at Niagara made them commercially successful.

The first electrolytic alkali plant was developed at Rumford Falls, Maine, under the patents of LeSeour. Castner invented the mercury cell for electrolytic alkali and installed it at Niagara Falls, producing caustic soda and chlorine. The Roessler and Hasslacher Company bought caustic soda and chlorine from the Castner Company and made metallic sodium and chloroform. They had been producers of sodium and potassium cyanide in Germany and they conducted that branch of the industry in Niagara Falls. The Oldbury Company had developed phosphorus and chlorates in England. They brought their process to the United States and became one of the pioneer concerns in the Niagara Falls development.

At this time a research organization was formed in Niagara Falls This organization developed alundum, which was taken over by the Norton Company. The same group developed ferroalloys for the Carbide Company.

In 1902, under the patent of Bradley and Lovejoy, nitric acid was made at Niagara Falls by the Atmospheric Products Company, using the arc process. In 1909 the American Cyanamid Company of Niagara Falls, Ontario, turned to the cyanamid process for making nitrogen compounds developed by the Germans, Frank and Caro, in 1895 to 1898. In this process calcium carbide plus the nitrogen gave calcium cyanamid. In 1910 Haber announced his process for the direct synthesis of ammonia from nitrogen and hydrogen.

Beginning of the coal-tar industry. Coal-tar distillation, a chemical industry branch of great importance, was started in this country in 1882 on a commercial basis by H. W. Jayne, who made benzene, nitrobenzene, and naphthalene in Philadelphia. His plant was taken over by the Barrett Company in 1888 and moved to Frankfort, Pennsylvania.

Jacob Schoellkopf, a Buffalo tanner, became interested in the new coal-tar dyes discovered in Europe and set up a small plant for their manufacture. This company was finally taken over by other interests and became the National Aniline and Chemical Company. The American dye industry, however, did not amount to much until the First World War, when chemical dependency on Germany was ended and Government protection and encouragement brought a rapid growth—too rapid, in fact, as it turned out in 1921 and 1922. In the latter year textile producers and dye users openly expressed their dissatisfaction with the quality of dyes produced and the high prices asked. The new industry was overdeveloped to the point where conditions and products were not to the interest of all concerned. Finally, when prices had to be reduced, quite a few high-cost producers were eliminated.

Rayon and plastics. The rayon industry was developed in France. The first successful commercial plant in this country was established in 1910 at Marcus Hook, Pennsylvania. In 1912, approximately 1,500,000

pounds of rayon were imported into the United States. This country now produces more than three quarters of the world's supply.

Celluloid, first made by Hyatt in 1869, and Bakelite were the forerunners of today's huge plastics industry, which though technically a division of chemical industry has by virtue of its rapid growth and present-day importance earned the right to an industry classification of its own. It is now one of the chemical industry's best customers, and this, together with the chemical nature of its operations, has resulted in most of the large chemical companies going into the plastics manufacturing field.

The DuPont contribution. Any discussion of the development of American chemical industry must include the name of DuPont. The DuPonts were among the earliest chemical manufacturers on this side of the Atlantic, having established a powder mill at Wilmington, Delaware, in 1802 at the request of Thomas Jefferson, and today the company founded on these small beginnings towers in size above all others in the chemical field. Since the manufacture of explosives involved primarily nitrogen compounds, it was natural that, with the development of organic chemistry based largely on nitration processes, the company expanded to dyestuffs, solvents, lacquers, rayon, plastics, and allied products. The growth of the company came about from its own developments and from acquired processes.

The American Chemical Industry Today[2]

Products. Products of the chemical industry may be classified in three general groups according to the use to which they are put:

(1) Materials which are the bases for production of other raw materials (twice removed from the consumer) Example: benzene, from which phenol is made, which in turn is used as a raw material in the manufacture of lacquers and plastics.

(2) Raw, or processing, materials used in the manufacture of finished products (once removed from the consumer). Example: tetrasodium pyrophosphate, an ingredient used in the manufacture of soaps and washing powders.

(3) Finished products ready for the consumer. Example: paradichlorobenzene, commonly sold as moth crystals. It should be pointed out that, although many chemical manufacturers make finished products that are ready for the ultimate consumer, rarely does the manufacturer actually sell to the consumer. Retail selling of chemicals is generally handled by jobbers or packagers, who buy the bulk material and package it under their own name. (This is discussed further under Marketing of Chemicals, page 532.)

bein

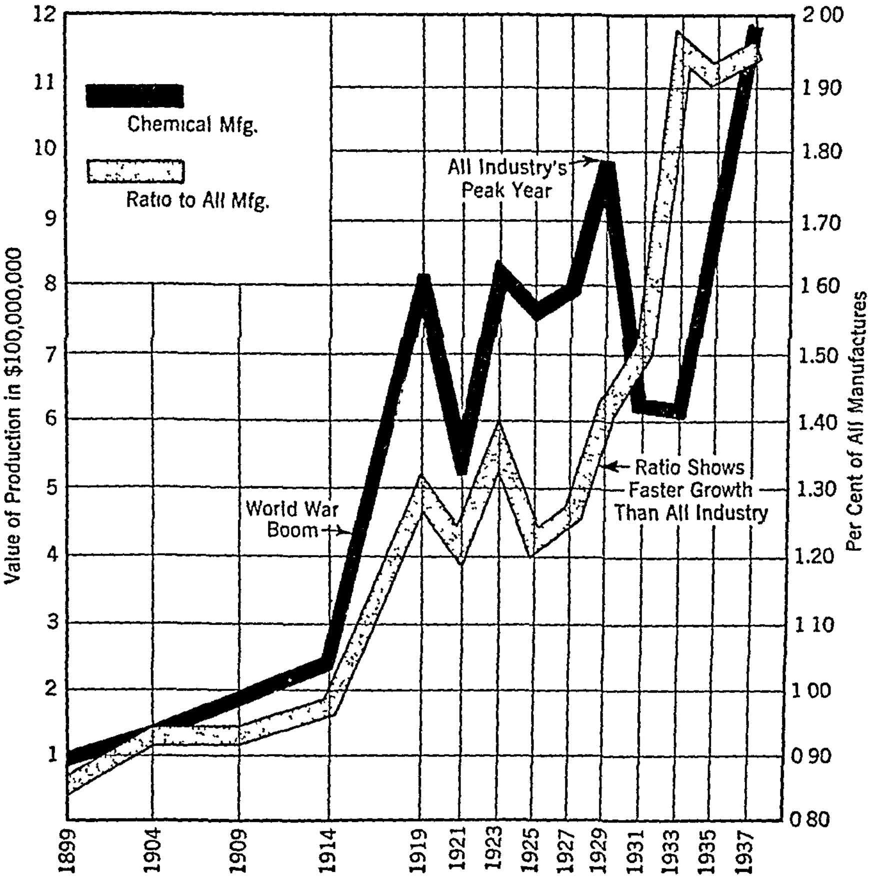
was deossible, in the case of a large company, that all three of these experimenould be made within the single company. In more cases,

sylvania, whe n of certain important chemical products, see Chapter XXIV in

oke; this was in is book (1932).

Che In that sam

however, they would be made by three different companies, all classified as chemical companies but each confining its operations to a single more or less defined field within the wide limits of the industry. Thus the chemical industry in the broad sense is one of its own best customers. This is a characteristic found in few other industries.



Source. "Chemical and Metallurgical Engineering" McGraw Hill Book Company, Inc., New York

FIG. 1. Growth of the chemical industry.

Raw materials. The principal primary raw materials of the chemical industry are coal, sulphur, limestone, salt, mineral ores, petroleum, air, and water. From these materials of nature are made both finished products and the secondary raw materials mentioned in the preceding section. Rising in importance but yet not approaching these mineral raw materials in volume used are the plant raw materials. Outstanding among these are: wood, from which is made rayon, plastics, and some synthetic vanilla; cotton, which goes into a large part of the cellulose plastics; and soybeans, flaxseed, peanuts, and other sources of vegetable

oils, which are used in paints and by hydrogenation are made into lard substitutes and other products.

Location. Chemical manufacturing is not a highly localized industry, despite the fact that fully half the production is concentrated in four states, which in order of importance are New Jersey, New York, Pennsylvania, and Illinois Markets and transportation are generally more important than sources of raw material, labor, and power, thus explaining the *chemical concentrations in the* New York, Philadelphia, Pittsburgh, and Chicago industrial areas. On the other hand, cheap electric power was the attraction that made Niagara Falls the country's chemical capital earlier in this century. Coal, gas, oil, and salt combine to give Charleston, West Virginia, her present claim to chemical fame. The South, Southwest, and Pacific Coast are increasing in chemical importance because of a combination of both markets and convenient raw materials.

A typical problem of chemical-plant location is represented by the phosphate-manufacturing operations of Monsanto Chemical Company. Phosphate ore deposits lie principally in Tennessee and Florida, but transportation costs on ore from these centers to processing plants in the principal market areas would be prohibitive because of the low percentage of phosphorus in the ore. The company found that it could strike the most favorable transportation balance by setting up a plant in Tennessee to extract the pure phosphorus from the ore and then ship this in tank cars to plants at Anniston, Alabama, East St. Louis, Illinois, and Trenton, Michigan, where it manufactures the important industrial phosphates close to their principal markets.

Markets. As has been mentioned, the chemical industry is not a consumer industry. The market for its products is comprised largely of other industries.

Although three large companies account for between one half and three quarters of the capitalization of the chemical industry, it cannot be said that the industry or its markets are dominated or controlled by these companies. The reason for this is that, instead of being built upon a few products which have similar uses, as in the case of steel and automobiles, the chemical industry supplies thousands of different products, most of which are for distinctly different uses. It can be said, in fact, that the chemical industry is probably the most diversified of modern industries. Not only does each of its thousands of products serve a different purpose, but in the case of many of these they serve several different purposes in different industries. This has a stabilizing effect on the market and on the industry as a whole.

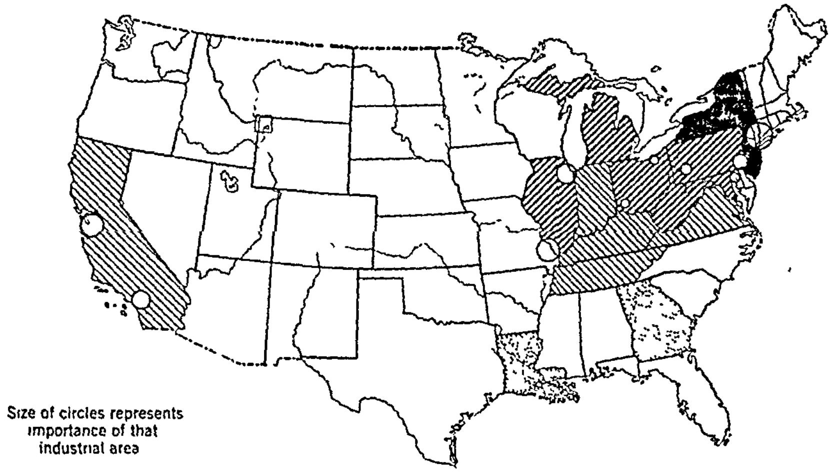
This characteristic of diversification of products and markets applies not only to the industry but to most individual chemical companies as well. Several of the larger companies, for example, make hundreds of different products which serve as many as 50 to 100 different industries.

There are many cases in the chemical industry today where a small company happens to be the major producer of a given product. Because of the many chemicals made, it can be said that in general any single manufacturer, regardless of size, competes on a product by product

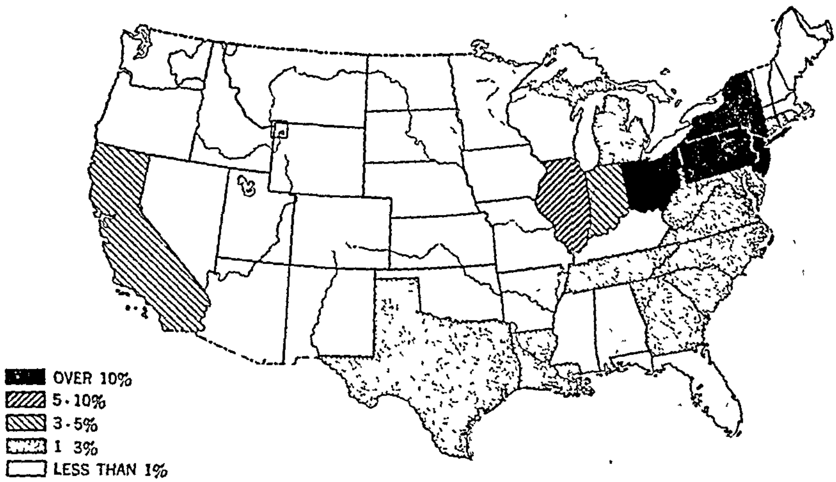
basis with only a part of the rest of the industry. Thus it is understandable why one company or several, no matter how large, would have difficulty in controlling the industry.

Operating Characteristics

Characteristic of the chemical industry is its greater dependence upon technology than upon artistry and manual skill in its plant operations as compared with most other industries. The nature of the materials it works with, most of which are in liquid or gaseous form during processing,



WHERE CHEMICALS ARE MADE



WHERE CHEMICALS ARE CONSUMED

Source "Chemical and Metallurgical Engineering" McGraw-Hill Book Company, Inc, New York

Fig. 2.

are inherently such that they can be handled readily in closed systems by automatic equipment. Thus plant equipment, fuel, and power loom large in the operations picture of a chemical plant. Great electrochemical plants often require more current than large cities.

High productivity. As a result of advances in technological methods, the output of chemicals per wage earner has advanced steadily for many years. Today nearly three times the quantity of goods is made per man-hour as was produced in 1919. Some labor leaders have worried about this development, thinking that tripling the productivity means that only one third as many men can find work in the industry. That has not been the case. On the contrary, a very definite benefit has developed both for the public and for labor.

A natural result of high productivity has been lower cost per unit of goods made. It has been a consistent policy of the chemical industry to pass on to the customer and to the wage earner as much as possible of this benefit. The rate paid per hour to highly productive employees has been constantly raised, as is shown in the next paragraph. The prices of chemical goods have been constantly lowered, as will be shown in a later section. And finally, the industry has been able to expand continuously, making for a constant increase in the total number of employees.

Employment and wages. Employment in the chemical industry is stable and well paid. Significant employment and wage trends in the industry are shown by the charts on the following page.

Depressions affect chemical enterprise somewhat, but not so seriously as they do the average for all factory employment or payrolls. This is natural, because chemicals are essential commodities for much of everyday living. Employment, in hours worked per week, has been much more constant in chemical plants than for all factories. There has been definite shortening of hours in times of slack business, but the total swing back and forth has been small.

Because chemical enterprise is so intensely technical it needs highly skilled workmen, generally speaking. It has relatively little need for large numbers of unskilled operators. In many cases safety alone demands that wage earners be alert and of high intelligence. The average annual wage for wage earners in the chemical industry in 1937 was $1,485.

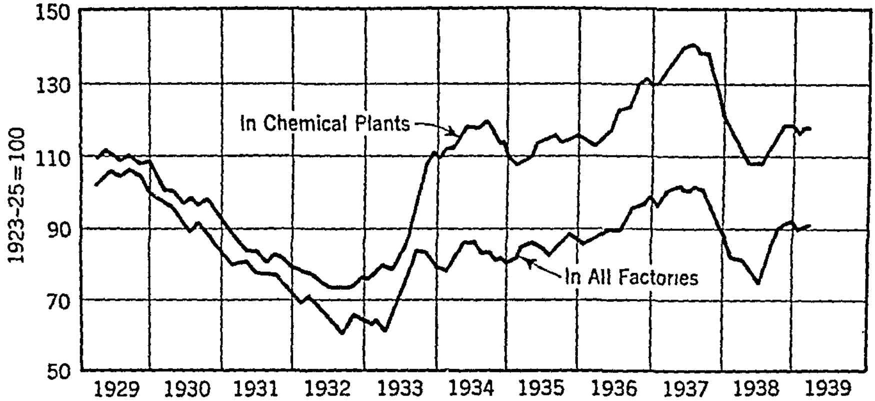
Management of chemical enterprise is necessarily entrusted to technical people. Those untrained in chemistry and engineering could not manage much of this business. Many of the jobs that in mechanical industries can be filled by experienced men without special training are in chemical industry necessarily assigned either to men of long training or more often to college graduates who have had professional education in chemistry or chemical engineering.

According to one source, the turnover of wage earners in a representative sample of chemical industry in 1937 was 33 per cent as compared with 53 per cent in all manufacturing industry.

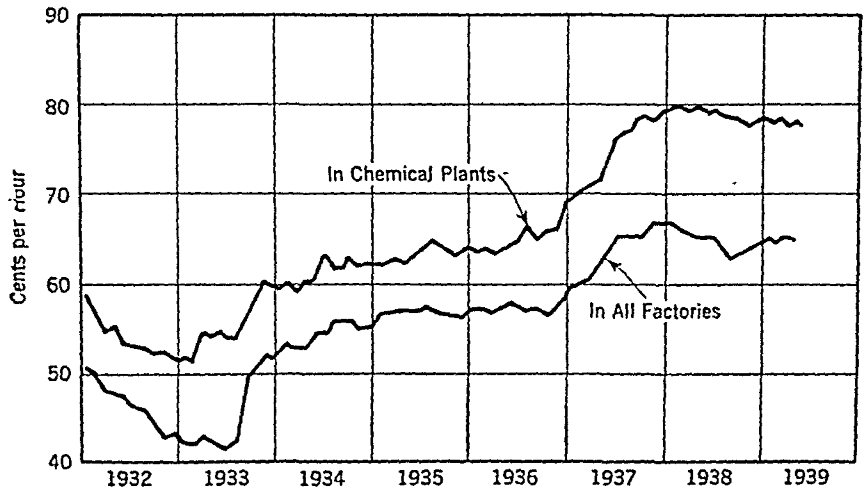
A study by the National Industrial Conference Board in 1937 brought out the fact that the capital investment per wage earner in the chemical

industry amounted to $11,250 as compared with an average of $7,000 per wage earner for all manufacturing business. The value of goods made per wage earner is likewise higher in the chemical industry. Based on sales value of products, the figure in 1937 for chemical industry was $11,800 per wage earner as against $7,090 for all industry.

Salaried employees and technical workmen play a larger part in chemical industry than in most industry. Census figures show that, for all industry, 88 per cent of the workmen are wage earners, but in chemical manufacture only 82 per cent are of this class. In all kinds of industry,



MONTHLY INDEX OF FACTORY EMPLOYMENT
Source - U S. Department of Labor



AVERAGE HOURLY EARNINGS
Source - U S Department of Labor

Fig 3.

about 1 per cent of the persons employed in manufacturing are officers. The plant supervisory staff is only 3 per cent in the average industry, as compared with 6 per cent in chemical making. Clerical workers constitute 8 per cent of the payroll, two thirds of the salaried employees, in the average factory, but they are 12 per cent of the payroll in chemical industry.

If to these factory employees are added the general administrative, research, and sales groups, an even greater deviation from the average by chemical industry is found. In such technical business, a large percentage have scientific or engineering training; even the sales personnel is largely so trained.

Coproducts. As has been mentioned, much of chemical industry is a multiproduct business. A raw material is taken as nature provides it and is processed primarily to make one commodity. But there are many other components and derivatives obtained from the raw material. For greatest efficiency, all must be used. Otherwise there is economic waste.

A great deal of the chemical research of recent years has been undertaken to offset the problems of by-products—or coproducts, as they are now more accurately called—and wastes. Not infrequently, new products and new services of greater importance have developed. In a few cases, processing the old coproduct has become as important as, and occasionally more important and more profitable than, the original primary activity.

An important secondary benefit of this type of development has been the practical elimination of waste-disposal problems. Chemical industry now contributes no more, and very frequently much less, to the pollution of streams, rivers, and harbors than do municipalities themselves. Today, as a result of progress in research, it is often profitable, as well as socially desirable, to keep waste products out of waterways.

Obsolescence. Obsolescence of equipment and methods is an operating factor that must be reckoned with in the chemical industry to a greater extent than elsewhere. With the industry progressing at its present rate, new processes and products and new ways of making old products are continually emerging from the research laboratories. Existing equipment may quite possibly be rendered obsolete overnight. In most cases, however, chemical plant equipment is flexible enough in its design to permit frequent modernizations without scrapping an entire plant, so that the bogey of overnight obsolescence is not as bad as it is sometimes pictured. In fact, it is often quite possible and economically advantageous to convert one process over into another for making an entirely different product, so great is the flexibility of modern chemical engineering design. Nevertheless the depreciation rate of most chemical equipment is relatively high.

Cost of production. Because of the wide diversity of products, it is impossible to give typical costs of production of chemicals. Aggregate raw material and labor costs for the entire industry are shown by the following table based on the United States Census classification of the chemical industry:

TABLE I

TRENDS IN INTERNAL COSTS OF THE UNITED STATES CHEMICAL INDUSTRY

(In per cent of total production.)

Census Year	*Cost of Materials*	*Wages and Salaries*	*Other Costs*
1849	65.3%	8.4%	26.3%
1859	65.8	8.2	26 0
1869	60.4	9.7	29.9
1879	61.6	9.6	28.8
1889	56.2	13.1	30.7
1899	53.9	14.1	32.0
1909	56.1	20.1	23.8
1919	62.8	15.9	21.3
1929	52.3	15.1	32.6
1935	51.1	15.7	33.2

A study of the costs of 29 chemical manufacturers for the year 1938 was made by the National Industrial Conference Board. The firms selected were a representative cross-section of the industry, including small and medium-sized companies as well as several very large ones. A summary of the results is as follows:

Total sales realization in 1938		$746,495,169
Cost of goods and services purchased from others	48.3%	
Wages and salaries	27.8	
Reserves set aside for amortization of fixed and tangible assets	7.0	
Federal, state, and local taxes	4.8	
Gross profits, including reserves set aside for bad debts, insurance, pensions, contingencies, *etc.*	12.1	
	100.0%	

It will be noted that there is a discrepancy between the percentage shown for wages and salaries in the Conference Board report and that shown in the table above which is based on Census of Manufacturers figures. The reason is found in the fact that the figures reported by the Census include only the compensation paid to employees engaged in the manufacturing part of the enterprise. The Conference Board figure includes all compensation whether the employees be in production, sales, management, or research.

Research

It has been said that technical brains are the most important raw material of the chemical manufacturer. No other division of American enterprise uses so large a percentage of its employees on research and development work aimed at the creation of new products and the improvement or more economical production of old ones. Research is the lifeblood of the chemical industry and of individual chemical companies,

for without it a company today comfortably situated may tomorrow find itself floundering in the wake of its more aggressive research-minded competitors. Particularly in the organic field of chemical industry are the results of planned research evident today in the constant stream of new products coming from the laboratories, most of them for specialized service in industry, never to be seen by the man in the street.

A national research project sponsored by the Works Progress Administration in 1936 and 1937 shows that about 300 research workers are so engaged for each 10,000 persons on the industry's payroll. This is exceeded only by the petroleum industry, which has come up so rapidly in recent years that it now is the largest employer of chemical and chemical engineering graduates. Of 25,000 technically trained men and women who have gone into research work since 1927, more than 40 per cent have found employment in the chemical and petroleum industries.

Much of the chemical sales dollar is paid out in research. The 1938 National Industrial Conference Board survey shows that 3.3 per cent of the gross income of chemical companies was paid out in 1938 for research alone In the organic chemical division of the industry, the figure ranged between 4 and 5 per cent.

One factor about chemical research that is frequently not understood by those unfamiliar with the industry is the time element involved. The fruits of research do not materalize overnight Most major research developments require a period of years and many man-hours of laboratory work from the time the idea or problem is first conceived to its appearance as a new product or process. After the basic work on Lucite, DuPont's new crystal-clear plastic, was finished, it is said that it took a whole staff of technical men 5 years to perfect the product and its method of manufacture before it was publicly announced in 1937.

Marketing of Chemicals

Marketing methods. In many respects, the marketing of chemicals is no different than the selling of other industrial goods. By far the greater portion of the products of chemical companies is sold directly to the industrial user, however, and as contrasted with products sold by dealers or at retail, some significant modifications in marketing methods must be introduced.

This dominance of direct selling considerably reduces the cost of distribution of chemicals as compared with most types of manufactured goods A picture of the way in which 555 chemical producers accomplish the primary marketing of their goods is shown in the following data from the United States Census of Manufacturers, 1935:

How Sold	*Value of Sales in Dollars*
Direct to industrial users	$216,591,000
Through wholesale branches	203,249,000
Through wholesalers and jobbers	83,964,000
Through retail stores	6,635,000
Direct to household consumers	532,000

Broadly speaking, the cost of administration and selling of chemicals is about 15 per cent of the factory cost.

Because of the very specialized nature of chemicals, there must be closest coöperation between the producer and customer, thus giving rise to the necessity for sales engineering and technical service—a distinctive feature of this and a few other industries. For this reason most chemical salesmen are technically trained, and many have had experience in research or production work. Their work as salesmen consists largely of showing customers how chemicals can be used profitably in their operations. Frequently the chemical company, on the recommendation of its salesman or technical-service representative, undertakes coöperative research with a customer on problems involved in the use of a particular product. The salesman in such cases acts as contact man between his own company's research organization and the customer.

Advertising and sales promotion have their place in chemical selling, but the techniques used are somewhat different than in the selling of less technical products. Chemical advertising is used chiefly as a means of distributing technical information about the product and its uses. Appeals to reason and intelligence are vastly more effective in selling chemicals than are appeals to emotion.

Because one chemical can often be replaced by another or be made by a different process, intercommodity and interprocess competition are important factors in chemical marketing. Coproducts and waste products offer puzzling problems since it is usually necessary to find a balanced market in order to spread the cost on an equitable basis. Transportation and shipping sometimes cause large items of expense, and may become a considerable factor in delivered costs.

Chemical prices. A gradual but steady decline in prices has characterized the growth of the chemical industry over a period of years, and this has occurred in the face of a constant rise in production costs and taxes. Rising costs largely have been offset by improving efficiency in both production and distribution. As far as fluctuation of prices within the major trend is concerned, however, chemical prices are more stable than those for many other industrial goods and far more stable than prices of farm products, foods, and most consumer's goods.

Illustrative of the stability of chemical prices is the fact that, even during the 1936-1937 inflationary boom, chemicals, as measured by the *Chemical and Metallurgical Engineering* monthly index of chemical prices, advanced only 2 per cent between October, 1936, and April, 1937, while the general price level rose almost 15 per cent.

In any discussion of chemical prices it is important to realize that this group of commodities includes many individual items which are subject to conflicting price influences. These differences between individual commodities are probably more pronounced in chemicals than in any other major commodity group. It follows, therefore, that a company making a wide variety of chemical products will be less affected by price fluctuations than a company making fewer or less diversified lines.

Table II

10-YEAR PRICE TRENDS FOR 30 BASIC CHEMICALS

Commodities and Units of Sale	1937	1936	1935	1934	1933	1932	1931	1930	1929	1928	1927
Acetic acid, 28%, bbl., 100 lbs.	$ 2.43	$ 2.45	$ 2.43	$ 2.75	$ 2.79	$ 2.61⅔	$ 2.56	$ 3.39	$ 3.88	$ 3.53	$ 3.38
Muriatic acid, 18°, tanks, 100 lbs.	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1 00	1 00	.85	.85
Nitric acid, 36°, carboys, 100 lbs.	5.00	5.00	5.00	5.00	5 00	5.00	5 00	5.00	5.00	5 00	5.00
Sulfuric acid, 60°, tanks, ton	11.14	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	10.50
Alcohol, denatured, S.D. No. 1 gal.	.33	.33¼	.36	.34	.34	.31¼	.30½	.43	.49½	.46	.42
Methanol, crude, tanks, gal.	.33	.37	.33	.33	.33	.33	.343	.393	.544	.44	.67½
Aluminum sulphate, bags, 100 lbs.	1.35	1.35	1.35	1.35	1.25	1.25	1.27½	1.40	1.40	1.40	1.40
Ammonia anhydrous, cyl., lb.	.156	.15½	.15½	.15½	.15½	.15¼	.15¼	.15	.14	.13½	.11
Ammonium sulphate, 100 lbs.	1.37	1.248	1.20	1.23	1.12	1.04	1.50	1.75	2.20	2.43	2.38
Aniline oil, drums, lb.	.15	.14½	.14½	.14½	.14½	.14½	.14½	.15	.14½	.15	.15
Arsenic, white, pwd., lb.	.03	.03½	.03½	.038	.04	.04	.04	.04	.04	.04	.036
Benzol, 90% tanks, gal.	.16	.173	.15½	.193	.21⅔	.20	.19½	.21½	.23	.22	.24
Borax, gran., ton	40.67	44.00	42.00	40.00	40.00	42.25	60.00	66.00	53 00	62.67	90.00
Calcium carbide, drums, lb.	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.052
Carbon bisulphide, drums, lb.	05	.05½	.05½	.05½	.05¼	.05	.05	.05	.05	.05	.05½

Table II (*Continued*)

Commodities and Units of Sale	1937	1936	1935	1934	1933	1932	1931	1930	1929	1928	1927
Chlorine, liquid, tanks, 100 lbs.	$ 2.15	$ 2.15	$ 2.02½	$ 1.85	$ 1.76⅔	$ 1.70	$ 1.75	$ 2.50	$ 2.90	$ 3.45	$ 4.00
Ethyl acetate, drums, lb.	.07	073	.08½	.08½	.086	.10	.072	.10	.15	.11	.12½
Formaldehyde, 40% bbl., lb.	.05¾	.059	.06	06	.06	.06	.06	.07	.09	.08⅓	.10⅓
Lithopone, bags, 100 lbs.	4.26	4.60	4.50	4.50	4.50	4.50	4.50	5 25	5.50	5 50	5.50
Phenol, U.S.P., drums, lbs.	.13¼	.142	.143	.14¼	.14¼	14¼	.14¼	.14¾	.13½	.157	.17½
Salt cake, bulk, ton	13.00	13.00	13.00	13.00	13.00	14.25	15 00	17.50	17.00	15.00	17.00
Soda ash, light, 58% bags, 100 lbs.	1.25	1 23	1.23	1.23	1 20½	1.15	1.15	1.32	1.32	1 32	1.32
Caustic soda, 76% solid, drums, 100 lbs.	2.60	2.60	2.60	2.60	2.51⅓	2.50	2 50	2.90	2.70	2.80	3 00
Sodium bichromate, casks, lb.	.06⅝	.06⅞	.059	.05⅞	.048	.05	.06⅞	.07	07	068	06⅛
Sodium phosphate, tribasic, bbl., 100 lbs.	2.10	2 00	2.00	2 10	2.15	2.60	3 06	3 37½	3.30	3 50	3.50
Sodium silicate, 40° drums, 100 lbs	.80	.80	.80	.60	60	.65	.60	60	.75	.75	.75
Sulfur, crude, long ton	18.00	18.00	18.00	18.00	18.00	18 00	18.00	18 00	18 00	18.00	19.00
Turpentine, bbl., gal.	.48¾	.53¼	.50⅓	.43¾	.46¼	.42	.46½	.48	.57½	.57	.63
White lead, dry, casks, 100 lbs.	7.50	6.52	6.50	6 44	6.30	6.50	7.25	7.96	8.85	8.50	9.31
Zinc oxide, lead free, bags, 100 lbs.	5.71	5.06	5.66	6.30	5.75	5.90	6.62½	6.62½	6.62½	6.62½	6.62½

Source: *Chemical and Metallurgical Engineering* (McGraw-Hill Book Company, Inc., New York).

Exports and imports. Chemical industry maintains a fairly close balance between imports and exports. In 1936, according to the United States Bureau of Foreign and Domestic Commerce, this country exported $151,627,000 worth of chemicals and imported $131,859,000 worth. Thus the consumption of chemicals in the United States is about equal to production, and both of these amounts are approximately 11 times as important in dollars as are the goods coming in or going out.

The principal chemical exports in order of importance are: industrial chemicals; chemical specialties; naval stores, gums, and resins; pigments, paints, and varnishes; fertilizers; medicinals; and toilet preparations (not a strictly chemical group). Imports are: chemical raw materials, fertilizers, industrial chemicals, and coal-tar products.

Size of Chemical Enterprises

A chemical company in the popular mind has come to mean a giant corporation with far-flung production facilities and numerous laboratories full of white-clad chemists. While it is true that the three giants of the industry—E. I. DuPont deNemours and Company, Union Carbide and Carbon Company, and Allied Chemical and Dye Corporation—stand out conspicuously among the others, the chemical field nevertheless is composed largely of small companies. There are roughly 8,500 chemical enterprises reported by the Census of Manufacturers, and probably not more than 80 of these employ over 500 people. The greatest number of the smaller companies are in the drug, pharmaceutical, oil, turpentine, rosin, paint, fertilizer mixing, fine chemical, insecticide, and other such "specialty" lines.

The establishment of small chemical enterprises is favored by the fact that most chemical processes have to go through a period of trial and gradual evolution from a small beginning to larger, commercial unit production. Every new chemical product must go through these evolutionary stages, which may or may not require much capital, depending upon the difficulties encountered. Often the small enterprise will merge with a larger company to get the advantage of an established sales organization. Sometimes it will elect to expand its own facilities.

There has been nothing spontaneous about the growth of the chemical industry. It has resulted from the planned, aggressive search for new products and new markets by the companies comprising the industry. Simply because a company made chemicals has not meant that it was dragged forward by the achievements of the rest of the industry.

After the preliminary development stages, the size to which a new chemical process can go is pretty much limited by the existing market for the product. Since the industry is not a consumer goods industry but sells to other industries, it is in general not possible to create new demand through mass production and lower prices. Success and competitive survival of large companies in the automobile, appliance, and food industries depend primarily on the extent of their facilities and how they use them, and only secondarily on the existing demand for their products.

To these industries mass production generally means cost saving *and* a new and large market. In the chemical industry, however, mass production *may* mean cost savings and special advantage over competitors in the established market, but in general not a new and larger market unless the products are for ultimate consumers. The point of diminishing returns, in other words, in determining the size of a chemical plant is much more abrupt than in the case of most other industries and is determined almost entirely by the existing demand for the product. The program for increasing chemical sales therefore, as has been pointed out elsewhere

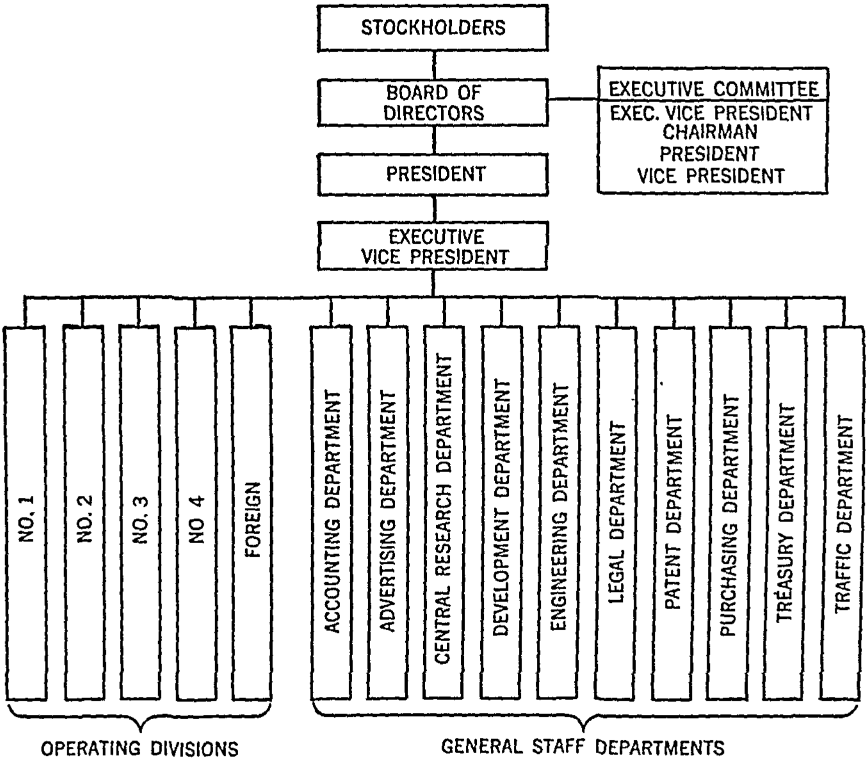


Fig. 4. Organization chart of a typical chemical company.

in this chapter, becomes one of research to find new products or to find new uses for old products. This has been the path of development followed by practically all of the larger companies in the industry today.

Organization of a Typical Company

The line-and-staff organization of a medium-sized chemical company is represented by the accompanying chart. It will be noted that executive control is centralized in a 3-man committee rather than a single individual. The members of this committee are relieved of all routine

TABLE III

FINANCIAL ANALYSIS OF LEADING CHEMICAL COMPANIES FOR 1936

(000 omitted)

Company	*Total Tangible Assets*[a]	*Total Current Assets*	*Total Current Liabilities*	*Net Working Capital*	*Net Property Investment*	*Net Sales*	*Net Income After Taxes*
Air Reduction Co.	34,855	21,709	4,215	17,494	13,695	27,833	7,064
Allied Chemical & Dye Corp.	190,956	97,201	13,654	83,547	76,609	—	25,323
Amer. Agricultural Chemical Co.	17,992	13,532	825	12,707	6,838	—	1,005
American Catalin Corp.	—	553	168	385	—	1,629	289[b]
Amer. Commercial Alcohol Corp.	8,749	10,266	6,925	3,340	5,937	35,463	887
American Cyanamid Co.	41,611	27,761	7,471	20,289	24,100	—	4,454
Amer. I. G. Chemical Corp.	40,556	2,955	927	—	—	—	4,684
Amer. Potash & Chemical Corp.	16,596	3,505	716	2,789	13,737	6,032	1,907
Amer. Zinc, Lead & Smelting Co.	7,348	3,665	848	2,816	4,532	9,621	52
Atlas Powder Co.	16,271	9,563	1,276	8,286	6,778	15,895	1,430
Baker (J. T.) Chemical Co.	1,493	996	364	632	738	—	182
Barium Reduction Corp.	742	401	61	339	392	—	—
Columbian Carbon Co.	—	7,487	1,522	5,965	37,695	13,872	4,021
Commercial Solvents Corp.	16,140	14,057	1,935	12,122	4,018	47,856	2,232
Compressed Industrial Gases Inc.	2,693	1,000	323	677	1,607	2,442	355
Consolidated Chem. Industries, Inc.	7,339	2,376	750	1,626	5,966	—	643
Davison Chemical Corp.	9,452	6,325	592	5,732	4,473	—	184
Diamond Alkali Co. and Subs.	40,947	—	—	—	30,858	15,723	—
Dow Chemical Co.	25,134	12,924	3,708	9,216	21,788	25,578	4,089
DuPont (E. I.) deNemours & Co.	536,317	155,229	32,307	122,922	221,989	260,333	89,884
Great Western Electro-Chem. Co.	3,096	1,304	361	942	2,100	2,719	475
Harshaw Chemical Co.	3,448	2,916	1,037	1,879	1,490	—	369
Hercules Powder Co.	32,495	17,833	2,778	15,055	16,355	36,740	4,284
Heyden Chemical Corp.	3,579	1,465	433	1,032	2,547	—	555
Hooker Electrochemical Co.	11,992	1,958	508	1,449	11,951	—	634[c]
Interchemical Corp.	11,585	7,881	1,920	5,961	5,624	17,446	1,269
International Agricultural Corp.	20,471	6,849	433	6,416	19,881	—	23

TABLE III (*Continued*)

Company	*Total Tangible Assets*[a]	*Total Current Assets*	*Total Current Liabilities*	*Net Working Capital*	*Net Property Investment*	*Net Sales*	*Net Income After Taxes*
Liquid Carbonic Corp.	15,678	8,528	1,502	7,026	8,652	13,705	1,106
Mathieson Alkali Works, Inc.	24,035	3,663	1,061	2,601	21,434	—	1,628
Merck & Co., Inc.	7,850	5,856	732	5,124	2,887	—	1,048
Metal & Thermit Corp.	5,889	4,817	359	4,457	1,431	—	—
Michigan Alkali Co.	—	20,081	3,554	16,527	25,980	—	—
Monsanto Chemical Co.	29,344	16,144	3,743	12,401	18,719	28,848	4,468
Niagara Sprayer & Chem. Co.	1,896	1,811	292	1,519	376	—	—
Noradel-Agene Corp.	1,770	1,100	716	384	1,386	2,043	1,224
Parke, Davis & Co.	36,087	24,781	6,165	18,616	6,380	—	9,213
Penna. Salt Mfg. Co.	13,930	6,995	1,286	5,708	8,222	—	1,285
Southern Alkali Corp. & Sub.	9,538	902	4,071	—	8,339	2,850	365
Squibb (E. R.) & Sons.	10,569	9,682	2,989	6,693	2,727	—	1,219
Sylvania Industrial Corp.	5,788	1,625	836	788	4,999	—	1,161
Tennessee Corp.	19,646	4,440	1,106	3,333	16,312	9,656	353
Tennessee Products Corp	5,775	987	84	903	5,989	—	36
Union Carbide & Carbon Corp.	247,036	97,040	24,398	72,641	178,765	—	36,852
United Carbon Co	14,539	2,752	912	1,840	23,067	9,019	2,202
U. S. Industrial Alcohol Co.	11,771	13,283	2,710	10,573	1,197	—	77
Victor Chemical Works	5,449	2,826	433	2,391	2,561	2,860	342
Virginia-Carolina Chem. Corp.	20,238	9,091	907	8,183	14,154	12,583	93
Westvaco Chlorine Prods. Corp.	10,192	2,096	322	1,806	8,386	6,913	626
Zinsser & Co, Inc.	831	439	213	223	934	1,151	27

[a] Total tangible assets consists of either fixed assets plus working capital, or capital stock plus surplus, whichever is lower
[b] Before Federal surtax.
[c] Before depreciation and obsolescence.
Source = *Ibid.*

duties, but each is responsible for policy determination and direction for a general phase of the business. One oversees financial and sales matters, another production and personnel, and the third research and development. This executive committee is responsible to the board of directors, and the managers of the operating divisions and heads of service departments are responsible to the executive committee. The widest latitude is given to the division managers, so that, in effect, each is running a small company of his own with his own production and sales forces. The service departments serve all of the operating divisions in their various specialized capacities but are responsible to the executive committee rather than to the division managers.

Future Outlook

It is always fashionable to forecast new eras. Every modern faddist envisions a new type of living or new prevailing habits that center largely around his own self-interest or fields of activity. Today, however, it is neither the chemical manufacturer nor his research man who talks most about our chemical future. Popular fancy has been so taken by many recent chemical developments that it is the man in the street who tells you that America is entering a new synthetic chemical era. Or he speaks knowingly of a new "plastic age."

Such terms may be more or less justified. As the result of research, there are available in this country and abroad today hundreds of new chemical compounds that were entirely unknown 10 or 20 years ago. Organic chemical research is such that these materials can now be "tailor-made" to fit almost any conceivable requirement for new industrial and household applications. Our great and growing family of industrial plastics does promise interesting and exciting competition with many of the standard materials of today.

It is, of course, absurd to assume that the new synthetic plastics are going to supplant all natural materials and completely recast the habits and living conditions of this country. But it is not a mistake to assume that progress in research will continue at an accelerated pace. In fact each new invention seems to inspire more new developments. Progress is self-catalyzing. One may reasonably forecast, therefore, more and more spending for research, more and more new opportunities for improvement, more and more new services, and many new advantages to the industry itself, to its customers, and to the general public.

25

The Paint, Varnish, and Lacquer Industry

The Early History of Paint

The source of color is light, and reaction to color is practically universal throughout the animal kingdom. Color has been developed by man to a very high degree. From the earliest times, its use has been general in connection with religious symbolism, personal decoration, and the ornamentation of habitations. The so-called "Azilian culture" of the Paleolithic Age, placed at about 12,000 years ago, is recognized chiefly by its painted pebbles; while the remarkable Cro-Magnons, who flourished in southern Europe some 15,000 to 20,000 years ago, left numerous paintings on cave roofs and walls which still arouse admiration. It is interesting to note that some of the pigments they employed are still important in the paint industry—lampblack, ocher, iron oxide, and other such materials. Similarly, the "bitumen" mentioned in the Bible is closely related to the asphaltum still employed in the manufacture of protective coatings.

The Egyptians used paint extensively for decorative and ceremonial purposes, and it is supposed that Greek art derived from that source and spread thence throughout the semicivilized world. Greek and Roman writers of the classic age—Dioscorides, Vitruvius, Theophrastus, and others—give us fairly comprehensive descriptions of the materials employed, as well as of their sources and uses. It is clear that a rather extensive industry had already developed and that many of the raw materials in common use today were familiar to the ancient civilizations: white lead, red lead, yellow ocher, iron oxide, vermilion, lampblack, and so forth. From Rome and Greece the production and use of paint and varnish spread throughout the rest of Europe in the track of advancing civilization, first for artistic and later for decorative and protective uses.

Origin and Development of the American Paint and Varnish Industry

Aboriginal natives used color. The first manufacturers in this country were the aboriginal natives. In common with all primitive peoples, they employed color in the symbolic decoration of their persons and

belongings. They operated mines of iron oxide and yellow ocher, collected and used the carbon black from smoke, and used clays for white effects and the juices of various plants for dyes. The sources of supply were localized and widely known.

Home manufacture of dyes by colonists. The early white colonists of the country apparently brought with them no knowledge of paint manufacture. It is known, however, that simple materials like whitewash and vegetable dyes of home manufacture were in common use and that the production of "naval stores," including turpentine, was encouraged by the mother country and developed into a highly important industry. Flax and hemp were also widely cultivated under the same stimulus, but apparently no attempt was made in colonial times to extract oil from the seed

Pigments imported from England. Up to the time of the Revolution there is no record of any attempt in the colonies to prepare either paint or varnish for sale, although it is presumable that private "bootlegging" of these products occurred. Paint as we know it today was not available even in England until a much later date, the pigments and vehicles being purchased separately and laboriously incorporated by the painter, with slab and muller. White lead was, for a long period, the important pigment in use, and the range of tinting colors available was limited.

A glimpse of conditions at the time is given by an advertisement of Mordecai Lewis and Company, in the *Pennsylvania Packet,* 1772, in which it announces the receipt from England of a variety of materials, including "linseed oil in casks, white lead ground in oil, red lead and vermilion, and whiting and chalk." That house, which later became one of the earliest manufacturers of white lead and later of colors is still operated by the same family, under the name of John T. Lewis and Brothers Company, and is a constituent unit of the National Lead Company.

First manufacturer of white lead in America. The first actual manufacturer of white lead in America was the firm of Samuel Wetherill and Son, which erected a plant in Philadelphia in 1804. The present owner of Wetherill and Brother is a member of the same family in direct line of descent. The second white-lead plant was also established in Philadelphia, by John Harrison, about 1811. The concern later became Harrison Brothers and Company and is now a unit of the DuPont organization.

Early grinding of pigments in oil. The grinding of pigments in oil was a rather late development, and it is not definitely known when or by whom the practice was originated. The probability, however, is that it was started in New York by the predecessors of John W. Masury and Son or Devoe and Raynolds Company Inc., or by Wadsworth, Howland and Company, of Boston—all of whom were manufacturers of oil colors for artists and carriage painters. It is known that, shortly after the Civil War, John W. Masury and Son produced a full line of tinting colors in oil and found great difficulty in overcoming the prejudice of the painters, who were accustomed to grinding their own colors. The ob-

vious advantage of the innovation, nevertheless, soon overcame the inertia of the craft, and all manufacturers very quickly followed the example set for them.

First ready-mixed paint. The manufacture of prepared, or ready-mixed, paints developed from the practices of dealers who prepared small quantities of paint at the request of lay customers. There are several claimants to the honor of the first adoption of this practice for commercial purposes. John Lucas and Company was certainly among the earliest, if not the first. This company began the manufacture of a line of ready-to-use house paints at its plant in Gibbsboro, New Jersey, in 1860, but the entire industry very quickly supplied ample competition.

The total number of paint, varnish, and lacquer manufacturers in the United States at this writing is approximately between 1,000 and 1,200, and of these not fewer than 800 produce prepared paints of some type, industrial or architectural, or both. The present annual output of the entire industry, in paints, varnishes, and lacquers, is valued at about $550,000,000.

The Raw Materials of Paint Manufacture

The materials of the great masters of painting were for the most part manufactured in their own workshops from jealously guarded secret formulas. The pigments included many of those used today: white lead, red lead, yellow ocher, vermilion, iron oxide reds, arsenical (Paris) green, the animal and vegetable blacks, lapis-lazuli blue (later, ultramarine and Prussian blues), a variety of vegetable-dye lakes, sepia, and asphaltum browns, and later zinc oxide, which first masqueraded as "silver white." The vehicles generally used were poppy oil, walnut oil, linseed and hemp oil to some extent, spirit varnishes, soluble gums, and copal varnishes. There was no commercial manufacture on an important scale.

Paint consists essentially of pigments, vehicles, volatile thinners, and dryers. The pigments constitute the solid, colored constituents; the vehicles, the liquid portion in which the pigments are suspended. The thinners increase fluidity but evaporate from the drying film, and the dryers provide certain metallic compounds which hasten drying.

Pigments

White group. *White lead.* The commercial production of white lead began in Holland some time during the sixteenth century, the process having been borrowed, it is believed, from Venetian practice. It was introduced into England toward the close of the eighteenth century and into the United States a few years later. It is now produced by several methods, but that known as the "Old Dutch process" retains its precedence. In outline, all processes depend on change of lead to the acetate and then on the action of moisture and carbon dioxide as the basic carbonate, with subsequent grinding, washing, and drying.

A large portion of white lead is marketed in the form of a linseed-oil paste, called "lead-in-oil." This paste is prepared by mixing linseed oil directly with the wet-press cake. The water is displaced by the oil, floats to the surface, and is run off.

Zinc oxide. The manufacture of zinc oxide on a commercial scale was begun in France shortly before the middle of the nineteenth century, and in America only a few years later. Two processes are employed; they are known as the "French process," in which vaporized zinc is brought into contact with air at a high temperature, and the "American process," in which zinc vaporized directly from the ore is oxidized in a similar manner. When the ore used in the latter process is associated with lead, the vapor of the latter is oxidized to lead sulphate, and the product is known as "leaded zinc." Such pigments are sold under names indicative of the lead content.

Sublimated, or basic sulphate, white lead, which is produced by a modification of the zinc oxide process from lead sulphide ores (galenite), is also extensively used.

Lithopone. Lithopone, a combination of zinc sulphide and barium sulphate, is produced by the double reaction, in solution, of barium sulphide with zinc sulphate, with subsequent furnacing, grinding, washing, and bolting. The standard product consists approximately of 72 per cent barium sulphate and 28 per cent zinc sulphide. The manufacture of this important white pigment was started in England about 1874 but met with little success until production was taken up in Germany some 10 years later. American manufacturers became interested during the early nineties, and during the past 10 or 15 years its consumption has grown to exceed that of any of the other white pigments. A variant of this pigment is titanated lithopone, which contains a percentage of titanium dioxide.

Other important white pigments of the same group are high-strength lithopones, containing a high percentage of zinc sulphide and pure zinc sulphide, which has very high opacity.

Other important white pigments. Other important white pigments of recent introduction are the titanium dioxide group, ranging from the pure titanium dioxide to various combinations of that pigment with barium sulphate or with the sulphate or carbonate of calcium. The high-color density of these pigments has led to a steadily increasing consumption.

The remaining white pigments of any special importance are the so-called "inert" pigments: barites, whiting, and other forms of calcium carbonate, various white clays, asbestine, and others. These all find some use as "extenders," as color diluents, or because of their physical properties. Asbestine is a notable example of this latter use, its acicular form retarding or preventing the hard-settling of the paint on long standing. The use of barites as a diluent of chrome green is standard because of the high cost and poor color of that pigment when undiluted.

Colored pigments group. The colored pigments used in paint manufacture cover a very wide range in respect to source, composition and

color. They may be roughly classified as "natural colors," "chemical colors," and "lake, or dye, colors."

Natural pigments. The principal natural pigments are the iron-earth colors—iron oxides—including ochers, siennas, and umbers. Some of these, when heated, take on additional oxygen with a change of color. The most familiar are umber, which changes from dull green to greenish brown; sienna, which changes from yellow to a deep brown-red; and others which change from yellow to red or from a greenish brown to a clearer reddish brown. The variety of these natural earth colors may be realized from the fact that a single manufacturer may offer as many as 100 of them.

Venetian red. Allied to the iron-earth colors is Venetian red, which is produced by the reaction of iron sulphate with lime, followed by washing and calcination.

Pigments from lead. Besides white lead, the metal lead yields several important pigments, which again vary in color according to treatment. The most important of these are red lead, the chrome yellows, and orange mineral. Red lead is obtained by the further oxidation of litharge (the monoxide). Orange mineral is produced similarly by the oxidation of white lead. Both operations are conducted at a low temperature in open furnaces.

Chrome yellows are lead chromates produced by precipitation of a lead salt in solution by potassium or sodium chromate, also in solution. Tungsten and molybdenum also enter into the composition of yellow and orange chromate pigments.

Quicksilver vermilions. The true "quicksilver" vermilions (Chinese and English) are mercury sulphide, produced either by precipitation or sublimation, but they have been largely replaced by "American vermilion," a basic lead chromate now used chiefly in rust-inhibitive paints, having been in turn largely superseded as a color by the aniline scarlets.

The remaining reds of importance are almost all in the dye, or lake, class.

Black. The important blacks are all chiefly carbon, from the various sources indicated by their names—lampblack, carbon black, boneblack, graphite, and so forth—the only exception of consequence being iron black, or ferric oxide.

Blues. The important blue pigments are Prussian blue, sometimes called "iron blue," ultramarine blue, phthalocyanine blue, and cobalt blue Prussian blue is prepared by mixing a solution of a salt of ferrous iron with a solution of sodium or potassium ferrocyanide, and by oxidation of the white precipitate. Ultramarine blue is a complex product made by calcining mixtures of clay, silica, sulphur, and carbonaceous material. Phthalocyanine blue is a compound of copper and phthalocyanine. Cobalt blue is mainly a cobalt oxide.

Brown. The pigment browns, excepting the lakes and other dye products, are mainly bituminous materials or mineral (iron oxide) colors.

Chrome green. Chrome green, the most important of this class, is

formed by the simultaneous precipitation of Prussian blue and chrome yellow. Chromium oxide is also an important green pigment.

Lake, or dye, colors. The list of lake colors and other pigments from organic dyes is so long and growing so constantly that its mere enumeration would overrun the space available for this entire chapter. Generally, they may be described as dyes precipitated on or with inorganic bases to form insoluble, highly colored pigments in a state of fine subdivision. Among the most important of them are perhaps the para-nitraniline, alizarine, lithol, toluidine, eosine, and azo colors; but, as already stated, the number and variety is endless, and no attempt at specific description is practicable. Two, however, require separate mention: toluidine-red and Tuscan red. The first-named is a brilliant red, widely used in many forms and for many purposes. The second is Indian red (iron oxide), on which an aniline lake is precipitated.

Vehicles

The purpose of the vehicle is primarily to hold the pigments in liquid suspension so that they may be applied in a thin, uniform coating. They have consisted mainly of drying oils, varnishes, and sometimes, more recently, of synthetic gums dissolved in appropriate solvents. The latter are of very recent development and are, at this writing, largely in the practical-experimental stage. In essence, they are closely allied to the quick-drying enamels, also of recent introduction.

Drying oils. The drying oils most widely used are linseed oil, tung or China wood oil, oiticica oil, and perilla oil. They "dry" partly through polymerization and partly through oxidation of their unsaturated fatty acids.

Linseed oil is expressed from flaxseed. The annual United States consumption of the oil is approximately 500,000,000 pounds.

Tung oil is expressed from the seeds of the tung tree, cultivated in the southern provinces of China and, during recent years, in our Gulf states, where the growing of it is being widely adopted. It is extensively used in the manufacture of varnishes, interior paints, and most waterproof coatings.

Perilla oil is obtained from perilla seed. It comes to this country chiefly from Japan. In its properties, it is essentially the same as linseed oil, although it is preferred to the latter for some purposes; but the supply is limited and irregular.

[illegible] are also used rather extensively, especially in [illegible] coatings; and soybean oil, which [illegible] important place in [illegible] converted into a drying oil [illegible] characteristics of tung oil [illegible]

[illegible]

[illegible]

of raw oils, so as to insure uniformity in chemical and physical properties.

Volatile thinners. The volatile thinners used in paint manufacture comprise mainly turpentine, the petroleum naphthas, and coal-tar naphthas. These are all designated as "thinners," or "solvents." Various esters, alcohols, and ketones are used for thinning nitrocellulose lacquers and some of the synthetic resin coatings. The purpose of thinners is to give proper fluidity without an undesirable excess of vehicle. For the most part, they evaporate entirely from the film.

Driers. The driers are metallic salts which stimulate oxidation of the drying oil and the consequent hardening of the film. The most important of them are compounds of lead and of manganese or of cobalt and are generally used in the form of their dissolved soaps. Each has different properties, and they are commonly used together in varying proportions.

Varnish. The raw materials for varnishes include the oils mentioned in the preceding paragraphs, natural and synthetic resins, thinners, and driers. Examples of natural resins are kauri from New Zealand, congo from Africa, manila from the East Indies, shellac from India, and rosin from the United States. Examples of synthetic resins are the glycerol ester of rosin, alkyd or glycerol phthalate, maleic acid, phenolic, vinyl, and cumarone. Other film-forming materials include cellulosic derivatives, rubber derivatives, urea-formaldehyde compositions.

Enamels. Varnish enamel is an imitation of the original fused vitreous enamel used for decorating metal. It was at first a spirit varnish, usually a solution of dammar gum in turpentine, in which the desired pigment was ground. This still finds some use. Practically all of the present-day vehicles are used in enamels according to the properties desired. Great fineness and uniformity are required in pigments intended for this use.

Manufacturing—General Procedure

Paints. In outline, the manufacture of paint involves grinding the pigments to a stiff paste in the vehicle, mixing the paste with additional oil or varnish and the volatile thinner and drier, tinting to the required shade with colored pastes, and filling and labeling the containers. All of these operations are performed by machinery.

Varnishes. The manufacture of oil varnishes involves cooking the resin and oil to form a homogeneous, stable system, and then thinning with volatile thinner. Driers may be added during cooking or after thinning.

The manufacture of spirit varnishes is simpler, the resin, or film-forming material, usually being dissolved by agitating it with a suitable volatile thinner. However, many types of spirit varnish require careful selection and adjustment of solvents and plasticizers.

The finished varnishes are filtered or centrifuged and then stored in large tanks, whence they are drawn off into cans, barrels, or metal drums for shipment.

Lacquers. Pyroxylin lacquer consists essentially of a solution of cellulose ester in a combination of volatile solvents, with plasticizers which insure the permanent flexibility and elasticity of the film. Natural and synthetic gums and treated oils are also used in great variety according to the purpose of the product.

The lacquer industry, although it has grown with unprecedented rapidity, is still in the experimental stage, and with new materials coming out of the laboratories will doubtless undergo many changes. In the few years since its appearance in its modern form, lacquer has largely replaced the older finishes in many fields, particularly in the automobile industry.

The Development of Lacquers[1]

The cease of World War hostilities in 1918 found our American manufacturers well overstocked with raw materials, ingredients, and finished products representing all types of war materials, for the expectancy of the duration of war was at least 3 years' longer than it actually proved to be. Our manufacturers of high explosives had great quantities of guncotton on their hands. Huge quantities of acetone had been manufactured and used to ship high explosives across the sea, and since for the production of every one part of acetone three parts of butyl alcohol were obtained by the fermentation process used, and since use of butyl alcohol was comparatively insignificant in comparison with that of acetone, immense stores of butyl alcohol were left.

During the year 1919 work was done on the reduction of the viscosity of nitrocellulose. Up to this time about 6 ounces of nitrocellulose to 1 gallon of amyl acetate was the usual amount of nitrocellulose to be made up in a workable solution. With the reduction of the viscosity of nitrocellulose, solutions containing up to 20 ounces per gallon of solvent were obtainable. A coating of a desirable thickness could be obtained in one or two applications of such lacquers.

It was not long before the acetylation of butyl alcohol and the reduction of the viscosity of nitrocellulose was under way on a huge scale. During the years 1921-1922, there appeared automobiles using the new finish, and a large market was thrown open to the manufacturers of lacquer. The following year saw research, control, and production increasing by large volume. New uses for this time- and space-saving finish were being found every day.

Liquids which for many years had been merely museum specimens, perhaps mentioned only in almost forgotten theses of graduate chemists, became important commercially as solvents for nitrocellulose. Heretofore, one could have numbered the commercially obtainable solvents for nitrocellulose upon his fingers, but now we needed books to number them and organic chemists to tell what they were. Fermentation, high pressure, catalysts, and various types of organic reactions by which these

[1] This section was written by A. W. Van Heuckeroth, lacquer chemist, Institute of Paint and Varnish R

solvents are manufactured are now the foundation of some of the huge industries of this country.

Residues left in the distillation flask, which caused the sweat and anger of many a chemist—who, after trying all types of caustic and acid reagents, would be forced to abandon his apparatus—were investigated. From experience with these residues consisting of condensed and polymerized reagents the research on synthetic resins was instigated Their manufacture and sale for replacing many of the irregular and high-priced natural gums and resins in the manufacture of lacquer followed in natural sequence. Phthalic anhydride-glycerin resins, phenol-formaldehyde, urea-formaldehyde, vinyl acetate, coumarone, and many other types of synthetic resins are now on the market. Combinations of synthetic and natural resins were also made.

It has long been known that liquids which are nonsolvents for nitrocellulose may be added in certain quantities to solutions of nitrocellulose. These nonsolvents, or "diluents," as they are termed, tend to lower the cost of the lacquer and in some cases to lower the viscosity and to decrease the rate of evaporation, thus allowing the lacquer to flow out. The best materials of this type are the alcohols and the aromatic hydrocarbons, benzene, toluene, and xylene. Benzene is not commonly used, because of its toxicity, while xylene is such a high boiler that it slows down the drying time to a large extent. This leaves toluene as the most desirable and probably the most used of the three. A number of aliphatic hydrocarbons, boiling between 100 degrees C. and 200 degrees C., for lacquer diluents, have appeared on the market. These hydrocarbons are very much cheaper than the aromatic, but they cannot be added to lacquer in as great a quantity as the aromatics, for in the same quantity they will cause precipitation of the nitrocellulose. It is then said of them that their dilution ratio is not so high as that of the aromatics.

For a number of years camphor was the foremost softener, or plasticizer, for cellulose nitrate. As long as celluloid was the chief product of nitrocellulose, camphor seemed best suited for the process, but when cellulose nitrate began to be applied in comparatively thin protective coatings, camphor was entirely too volatile and did not fill the place at all.

Semidrying and nondrying vegetable oils were brought into wider use as plasticizers. Methyl, ethyl, butyl, amyl, fenchyl, bornyl, and phenyl esters of phthalic acid are now made commercially. Phosphates, tartrates, adipitates, abietates, and esters of heretofore almost unheard-of organic acids are now being used as plasticizers in the lacquer industry. It was necessary to develop this vast list of compounds, for the use of lacquer on paper, cloth, wood, metal, glass, rubber, and other materials became quite as vast and even more varied.

The use of cellulose esters other than nitrocellulose as a protective and decorative coating has been held back only by the price of the materials and the scarcity of ingredients which will go with the esters. We have here a situation parallelling the situation which nitrocellulose itself was in before the war. One cannot help but feel that history will repeat itself and that, at some time in the near future, the chemist will

find the ways and means of lowering the cost of production and producing materials which best suit his needs.

The modern nitrocellulose lacquers may be divided into two main divisions, according to their mode of application, the brushing lacquer and the spraying lacquer.

Both consist of a nonvolatile portion containing nitrocellulose, plasticizer, resin, and pigment, a volatile portion containing solvents for nitrocellulose and diluent, usually a solvent for the resin. The solvents and diluents used in the spraying lacquer have a much higher evaporation rate than those used in the brushing lacquer. The viscosity of the lacquer is regulated for the desired thickness of the film.

Methods of Packing and Shipping[2]

Inflammable and noninflammable products. From the transportation viewpoint, the products of the paint, varnish, and lacquer industries are described individually as being inflammable or noninflammable. Those products which give off inflammable vapors as determined by flash point from Tagliabue's open-cup tester, as used for testing burning oils, at or below a temperature of 80 degrees F., are classified as "inflammable." Products which yield inflammable vapors only at temperatures above 80 degrees F. are designated "noninflammable."

The difference in the handling of the two groups in transportation arises from the fact that inflammable products are among articles classified as "hazardous" and subject to regulations of the Interstate Commerce Commission with respect to packing, packages, labeling, marking, and certification; the noninflammable group is handled regardless of such regulations.

Wood versus fiberboard boxes. In general, the products of the industry are distributed in boxed cans and in bulk, in kits, pails, drums, and barrels. Wooden boxes continue to be used but are being displaced rapidly by fiberboard boxes. Many factors have contributed to this change from wood to fiber, chief among which is the saving of space, which is important to many paint manufacturers. It requires very little manufacturing space to make the material but considerable floor space to handle it, and when to that are added storage facilities for the assembled wood boxes, a considerable area is required. The fiber box represents a reduction in the initial cost of the package and, being lighter, it represents economy in transportation costs also. From the standpoint of efficiency, the fiber package has proved entirely satisfactory. No necessary element of safety has been sacrificed. It is used extensively in the distribution of both noninflammable and inflammable products, being specifically authorized, subject to defined limitations, in the regulations published by the Interstate Commerce Commission.

Bulk goods are generally packed in wooden or steel packages of capacities from 5 to 55 gallons. For products classified as "not danger-

[2] This section was written by E. A. Leveille, Chairman of the Traffic Committee of the paint and varnish industry.

ous," the choice of packages is unrestricted, and for inflammables the packages must meet the regulations prescribed by the Commission as to construction, labeling, certification, and so forth.

Steel and other metal containers. Steel packages are becoming increasingly popular, and as experience demonstrates their safety, they are being increasingly used. Illustrative of this tendency is the order of the Interstate Commerce Commission in Docket 3666, effective July 15, 1931, to eliminate the 5-gallon restriction from specification 5 E (metal drums). This will provide an additional container for alcohol, lacquers, thinners, and other inflammables which can now be distributed only in the heavy returnable drum. These are exceptionally durable and satisfactory for many purposes, but there are situations in the trade more satisfactorily met by a container of lighter weight not intended for repeated service.

For the purposes to which it is adaptable the new package affords several advantages. First, experience has demonstrated that it provides every needed element of safety. Second, the initial cost is less than that of the returnable steel drum. Third, they weigh 30 pounds per drum less than the returnable drum, and on every 1,000 drums shipped there is a saving equivalent to the transportation charges of 30,000 pounds of the product—a substantial item. Fourth, a heavy inventory in containers is avoided Fifth, the transportation costs of return "empties" and the expense of cleaning, handling, and accounting is avoided. And sixth, it is especially serviceable in export trade.

Exporting[3]

For the most part, it is possible to sell liquid finishing materials abroad in United States gallon measure or fraction thereof. Paste goods usually can be sold in pounds, although some exceptions arise from time to time, making it necessary to sell in the metric system, or Imperial measure; but as a rule, this is not necessary. Exporting manufacturers should endeavor to sell in United States currency or its equivalent. It is usually possible to sell in this fashion.

Packing

Packing liquids for export is a problem that should be given the manufacturer's best attention. There are several can, case, and drum manufacturers who are in a position to furnish the manufacturer with appropriate styles of packing for overseas shipment. In addition, there are testing laboratories located throughout the United States which, for a nominal fee, can subject the manufacturer's packing to tests which will give fairly accurate information as to how their products thus packed will survive shipment.

[3] This section was written by Ralph Plowman, E. I. DuPont, de Nemours and Company, Incorporated.

General

The exportation of finishing materials from the United States is an important factor, as indicated by the tabulation shown below of total exportation for recent years from the United States of pigments, paints, enamels, varnishes, and lacquers:

Year	*Value in Dollars*
1935	$16,344,000
1936	17,789,000
1937	21,555,000
1938	18,655,000
1939	22,761,324

The late 1920's saw a considerable advance in exportation from the United States as compared with the total exportation from other countries, the change being due primarily to the advent of lacquers and the educational campaigns carried on by the various export manufacturers, either by trained men sent abroad or by advertising campaigns, or a combination of both, in an endeavor to convince the prospective user of the economy of buying quality products scientifically made for specific purposes. However, a large drop in actual exportations took place during the world-wide depression, and the recovery in the late 1930's brought the actual exportations approximately to the level of 1925.

Financing

The financing of a paint business is in all essentials the same as the financing of any other industry, the procedure differing only with the character of the enterprise, as with individual ownership, partnership, or with stockholders' ownership.

In the first two kinds of ownership, financial arrangements are usually made with local promotors. In the other, common stock alone or both common and preferred stock may be issued and sold through the promoters or through brokerage houses. The larger corporations in general are capitalized in this way. In the so-called "mergers," the identity of the merged units is usually maintained, and these generally conduct the financing of their currrent operations through their local banking connections. The financing of a new corporation or "merger" in this, as in any other industry, is usually effected with the advice and assistance of a promoter experienced in such undertakings.

The market of the industry is more or less seasonal, requiring larger sums for current requirements during certain months than during other periods.

Capital invested.[4] Statistics showing the amounts of capital invested in the paint- and varnish-manufacturing industry, for the Census years from 1859 to 1919, are given in the statement shown on page 553.

The Manufacturers' Census for 1899 and prior years covered both factory industries and the so-called "hand-and-neighborhood" industries,

[4] Prepared by the United States Bureau of the Census

whereas those for 1904 and later years were restricted to factory industries. Two percentages are therefore given for 1899, the first being based on the total for all factory and hand-and-neighborhood industries, and the second on the total for factory industries only.

TABLE I

CAPITAL INVESTED IN THE PAINT AND VARNISH INDUSTRY FROM 1859 TO 1919

Census Year	*Capital Invested in Paint and Varnish Industry*	*Per Cent of Total for All Manufacturing Industries*
1859	$ 2,695,850	0.27%
1869	13,225,140	0.78
1879	17,333,392	0.62
1889	45,318,146	0.69
1899	60,052,674	0.61[a] 0.67[b]
1904	75,486,214	0.60
1909	103,994,908	0.56
1914	129,533,935	0.57
1919	239,775,836	0.54

[a] Comparable with percentages for earlier years.
[b] Comparable with percentages for later years.

It will be noted that the capitalization of the industry increased almost 300 per cent during the 20-year period from 1899 to 1919, whereas the corresponding increase in the combined number of salaried persons and wage earners was only about 150 per cent. This relatively rapid increase in capitalization was due in part directly to the development and mechanization of the industry and in part indirectly to the decrease in the purchasing power of the dollar.

Number of Persons Directly Employed

Table II (page 554) shows the numbers of persons engaged in the manufacture of paints and varnishes, as reported for the years 1937 and 1939. This table, prepared by the United States Bureau of the Census, also shows the number of establishments, value of products, and wages paid during both years.

Social and Economic Importance of the Industry

The paint, varnish, and lacquer industry today stands high in relative social and economic importance. It furnishes the decorative and protective finish to an infinite variety of surfaces in both the architectural and the decorative fields. Billions of dollars are invested in this country in the building of our great industrial plants and in our homes. If for even a comparatively few years these buildings were left without a protective covering of paint, they would very rapidly depreciate in value. Frame buildings would rot and decay, and corrosion and rust would attack the steel structures.

TABLE II

SUMMARY FOR THE PAINT, LACQUER, AND VARNISH INDUSTRY FROM 1939 AND 1937[5]

(Because they account for a negligible portion of the national output, plants with annual production valued at less than $5,000 have been excluded since 1919.)

	1939	*1937*	*Per Cent of Increase or Decrease (−)*
Number of establishments	1,165	1,037	12.3%
Salaried personnel[a]	7,262	10,209	−28.9
Salaries[a b]	$21,005,212	$24,563,973	−14.5
Wage earners (average for the year)[c]	22,328	25,135	−11.2
Wages[b c]	$31,696,715	$34,313,228	−7.6
Cost of materials, supplies, fuel, purchased electric energy, and contract work[b]	$245,551,810	$264,382,190	−7.1
Value of products[b]	$434,938,751	$453,865,808	−4.2
Value added by manufacture[d]	$189,383,941	$189,483,618	−0.1

[a] No data for employees of central administrative offices are included.
[b] Profits or losses cannot be calculated from the Census figures because no data are collected for certain expense items, such as interest, rent, depreciation, taxes, insurance, and advertising
[c] The item for wage earners is an average of the numbers reported for the several months of the year and includes both full-time and part-time workers. The quotient obtained by dividing the amount of wages by the average number of wage earners should not, therefore, be accepted as representing the average wage received by full-time wage earners
[d] Equivalent to the value of products less the cost of materials, supplies, fuel, purchased electric energy, and contract work.

In factories, a coat of paint protects the machinery, keeps pipes and tanks from rusting and leaking, aids in sanitation (as painted surfaces are easier to keep clean), lightens dark rooms and corners, decreases upkeep costs by cutting down replacements due to deterioration, and in a hundred ways lowers costs; while at the same time it increases efficiency through better working conditions.

In the home, paint serves two very important purposes, namely, utility and beauty. The achievements of architects and builders, cabinet-makers, and decorators would be impossible without the aid and protection of paint, varnish, and lacquer. The house that looks sadly run-down and old becomes rejuvenated with a fresh coat of shining new paint Furniture of diverse surfaces and with all the tell-tale marks of wear and hard usage can be made of uniform color and pleasing freshness at the cost of little time or expense.

It has been estimated[6] that, if the annual per capita expenditure for paint products in the United States is $4.76, the annual economic saving per capita through its use may be as high as $28.70. The total annual

[5] Source: United States Bureau of the Census, *Preliminary Report, Sixteenth Census of the United States* (Washington, D. C., 1940), No 18818
[6] Gardner, Henry A., *The Economics of Paint* (New York, November 5, 1931), a paper presented before the American Society for Testing Materials.

saving is estimated at $3,445,000,000, the saving through the use of paint on exposed steel surfaces alone amounting to $450,000,000.

The paint, varnish, and lacquer industry gives employment directly to many thousands of workers, and indirectly to many thousands more in the painting craft, the chemical industries, and the producers of raw materials. Beauty, sanitation, and conservation are its by-products; and whatever changes technological development may bring, its future as a whole is secure and promising.

26

The Machine-Tool Industry

Introduction

For thousands of years, up to about 175 years ago, whenever metal was used it was shaped by hand. Whether in making such simple things as hinges and kettles or parts for such complicated contrivances as clocks and printing presses, iron and copper and brass and other metals were shaped either with a hammer while red-hot or, if cold, with files and *chisels and similar hand tools.*

However, about 175 years ago, men began to learn how to cut metal by means of machinery—in other words, by means of machine tools instead of hand tools. This made it possible to fashion metal objects to much more accurate dimensions and in much greater quantities than was ever possible by hand.

The ability to make metal products with machines instead of by hand, including the making of machinery itself with machines, was one of the most important of the revolutionary accomplishments that marked the transition into the modern industrial era. It ushered in the greatest period of technical advancement and brought the world the highest standard of living it has yet known.

Slowly at first, then in increasing tempo as they were perfected, machine tools have assumed a more and more vital role in the industrial scheme of things, until today it can be said, as Dr. Dexter S. Kimball of Cornell University has aptly put it, that machine tools are "the master tools of industry."

Machine tools defined. The National Machine Tool Builders' Association defines a machine tool as "a power-driven complete metal-working machine not portable by hand, having one or more tool or work-holding devices and used for progressively removing metal in the form of chips." Grinding, honing, and lapping machines are included in this classification, although the chips removed can be seen only under the microscope.

There are other important metal-working machines, such as presses, brakes, metal shears, forging and stamping machines, but these are not included in the category of machine tools because they do not remove metal in the form of chips.

Expressed in simple terms, a machine tool is a power-driven machine

used to cut or shape metal. In a sense, it may be compared to a lathe, a planer, or other woodworking device which produces the leg of a chair, for example, by shaping a block of wood to the form desired by cutting away the superfluous material.

Thus a machine tool takes a bar or block of metal, or even a rough casting like an automobile-cylinder block, and, by the various processes described in the following paragraphs, literally carves or bores the part to the shape required The outstanding feature of the machine tool of today is the speed with which it removes metal and the high degree of accuracy with which the work is done. In some cases, the permissible error is measured in tenths of thousandths of an inch.

Basic Machine Tools

The five basic arts. The variety and combinations of machine tools in use today are almost unlimited. The tools range in type from a small bench device which could easily be set up on a desk to mammoth machine tools weighing from 40 to 50 tons and requiring large space for operation.

Their functions, however, fall naturally into a classification which may be called the "five basic arts of metalworking." These functions are as follows:

(1) Milling, which consists of machining a piece of metal by bringing it into contact with a rotating cutter with multiple cutting edges. (Fig. 1)

(2) Planing, which consists of machining a surface by moving the work back and forward under a stationary cutting tool. This classification includes shaping, in which the tool moves in a straight line over a stationary piece of work. (Fig. 2)

(3) Turning, which consists of shaping a rotating piece by means of a cutting tool, thus generating a cylindrical surface. This process is exemplified by the ordinary lathe. (Fig. 3)

(4) Drilling, or boring, which consists of cutting, enlarging, or finishing a round hole by means of a rotating cutting tool. This process may be effected with either single or multiple spindle machines. In this class are included reaming and honing.[1] (Fig. 4)

(5) Grinding, which consists of shaping a piece by bringing it into contact with a rotating abrasive wheel. This process may be internal grinding (as in grinding a hole), or external cylindrical grinding (on the outside of a rotating piece), or surface grinding (on a flat surface). The process also includes such methods of finishing as polishing, buffing, and lapping. (Fig. 5)

Variations and combinations. More than a century of machine-tool development, most of it in recent decades, has resulted in many variations and combinations of these five basic machines. There are "broaching" machines, for example, which are like huge files, with each cutting

[1] Certain special types of machine tools known as "boring mills," in which the work is rotated and the cutter is held stationary, would be technically classified under the turning rather than the boring art.

edge a little higher than the one ahead of it. These machines are essentially planers but are particularly adapted to cutting odd-shaped surfaces. There are milling machines designed particularly for cutting gear teeth that are called "hobbing" machines. There are "turret" lathes, which are lathes so designed that the operator can bring a succession of different cutters to the work over and over again, one at a time, to perform the various operations required. There are "honing" machines, which consist of a rotating head bearing abrasive sticks, for extremely

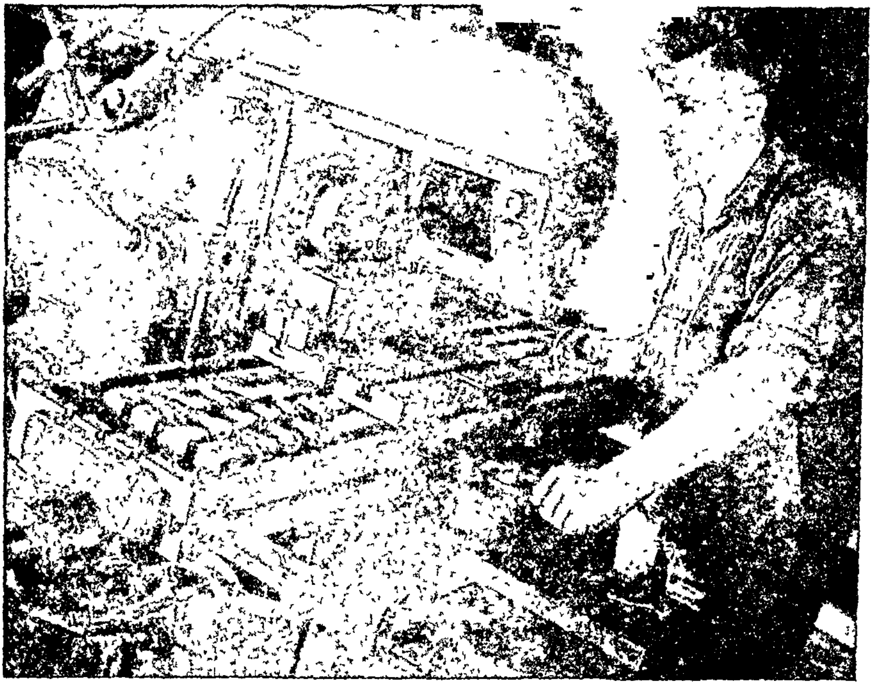


FIG. 1. Milling. The parts to be machined are passed back and forth under the two cutting wheels, which are rotated at high speed.

accurate boring of holes; "lapping" machines, for extremely accurate grinding; and many others.

In the same way, there are a number of machines that combine two or more different operations. There are combination boring, drilling, and milling machines, for example, and combination milling machines and planers. A turret lathe can turn, drill, and form at one time.

In addition, there are a number of machines that can make multiple cuts, for example, milling machines that finish two top surfaces and one side surface simultaneously, and machines that can drill over 100 holes at one time, such as those used in machining automobile cylinder blocks. Automatic machines that machine the end of a piece of bar stock in five different stages simultaneously and then cut it off to the desired length are in common use in industrial plants.

Importance of machine tools. As is evident from even a quick look at some of the most important types mentioned in the preceding paragraphs, the vital importance of machine tools in our modern industrial civilization can hardly be overestimated. Without machine tools it would be impossible to produce commercially most of our everyday necessities and luxuries. These include not only those products in which

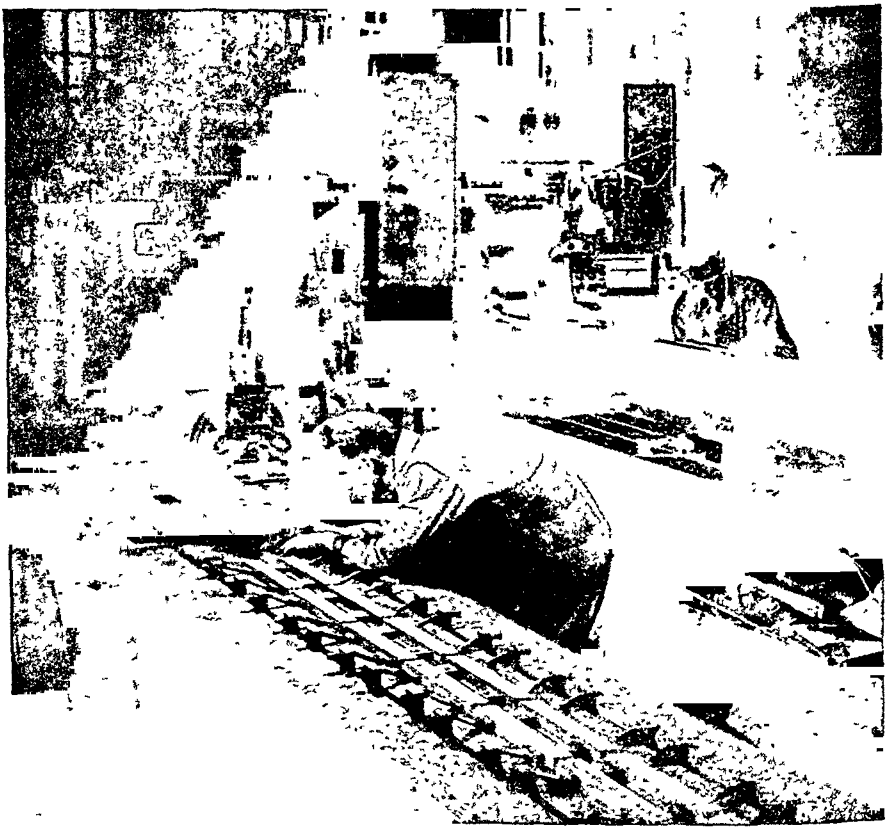


Fig. 2. Planing. The metal parts to be planed are accurately fixed into position on what is known as the "table" of the machine, seen in the foreground. The entire table is then passed back and forth under the cutters which the operator is adjusting In this way the whole line-up of parts is machined at one time.

metallic parts are obviously essential but also hundreds of others which, in their finished form, seem to bear no relation to the machine tool.

Automobiles, airplanes, agricultural implements, bicycles, business machines, ships and railroad trains, machinery for construction work, road building, mining, and producing petroleum, industrial and domestic electrical equipment, and hosts of other metallic utilities are produced by the machine tool or by machines made on machine tools.

Forests are converted into lumber and paper and rayon to the symphony of humming machines produced by machine tools. Food products,

drugs, toilet articles, sanitary preparations, and tobacco products of all kinds are processed, packed, and distributed by machinery or equipment which is made on machine tools.

Clothing is made on sewing machines, which are the products of the machine tool. Shoes, automobile tires, and other leather and rubber products in great variety are available because of the machine tool.

Even machine tools themselves are made on machine tools!

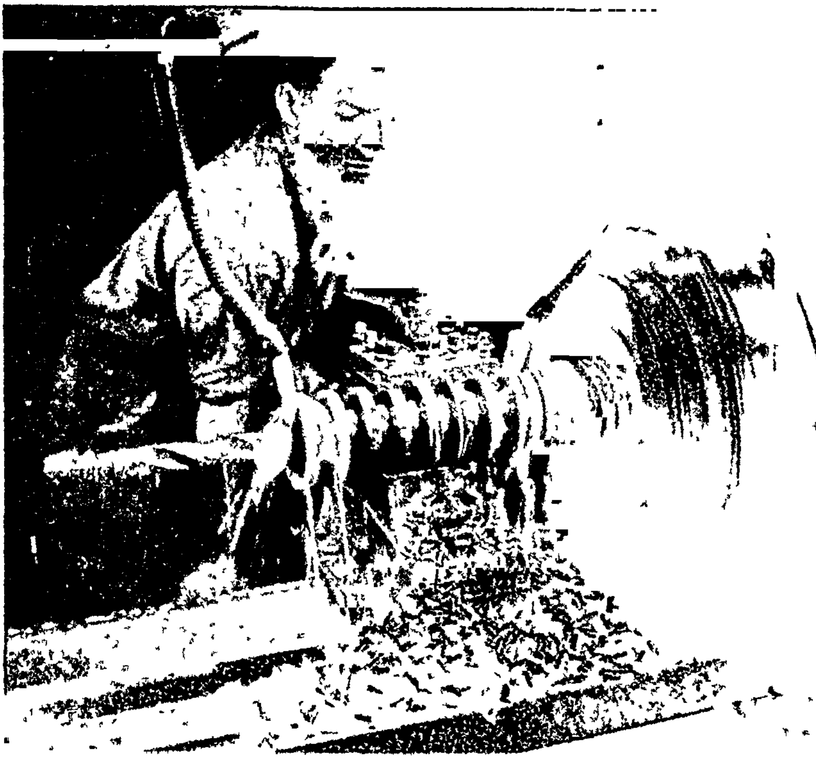


Fig 3 Turning Gear blanks being cut from a solid bar of steel on a lathe. When finished, the eight blanks shown in process are cut apart and sent to a milling machine, which cuts the teeth into the blanks.

One may sum it up by saying that, except for the living things that nature reproduces and the stars and planets, everything we see around us today is either made possible entirely or costs as little as it does because of machine tools.

Take the paper on which this is printed, for example. It may seem to bear no relation to metalworking machinery. Yet this paper was rolled on a huge paper mill. Like every other kind of a machine, a paper mill consists of an assembly of hundreds of individual metal parts—from tiny screws that weigh a fraction of an ounce to huge rollers that weigh perhaps 20 tons apiece.

Each one of these parts, small and large, was machined on a machine tool. That is, each part was bored, drilled, planed, turned, ground, or milled from a larger piece of metal. In this way, we could trace back to the five basic machine tools everything we see around us today that was ever touched by any kind of a machine.

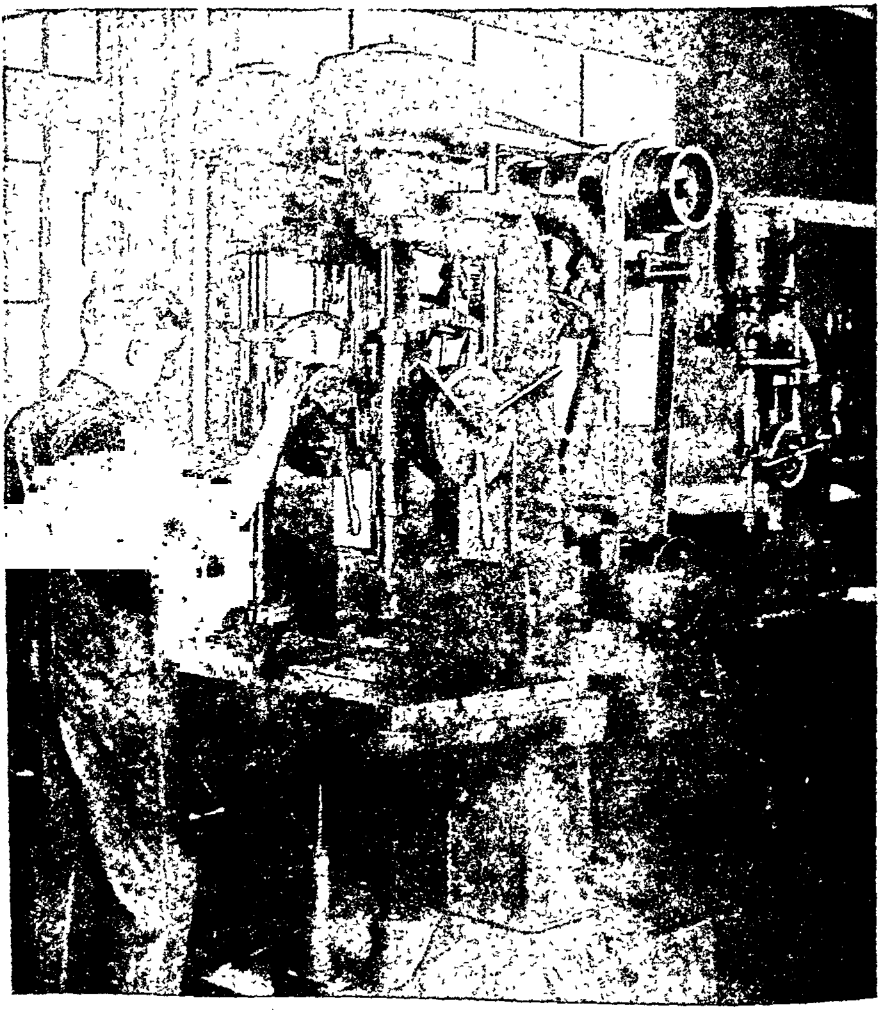


Fig. 4. Drilling (or boring). The part to be machined is held in a work-locating device called a "jig," which makes it possible to drill the hole quickly in exactly the same location in a number of different pieces

The Machine-Tool Industry in the United States

Early beginnings of the industry. As a distinct industry, the building of machine tools did not emerge to any extent until after the Civil War, although its beginnings in America can be traced back to about the

dawn of the nineteenth century and its beginnings in England and France to a somewhat earlier date.

Although advanced machine tools were conceived by a few of the geniuses of antiquity—including the famous Leonardo da Vinci—such conceptions, brilliant as they were, could not be carried out with the materials, tools, and technique of those days. Incidentally, it was the lack of machine tools which made it impossible for Leonardo da Vinci and other inventors who were far ahead of their time to build certain mechanisms which actually were entirely practical and which would have advanced the welfare of the world greatly could they have been constructed at the time they were conceived.

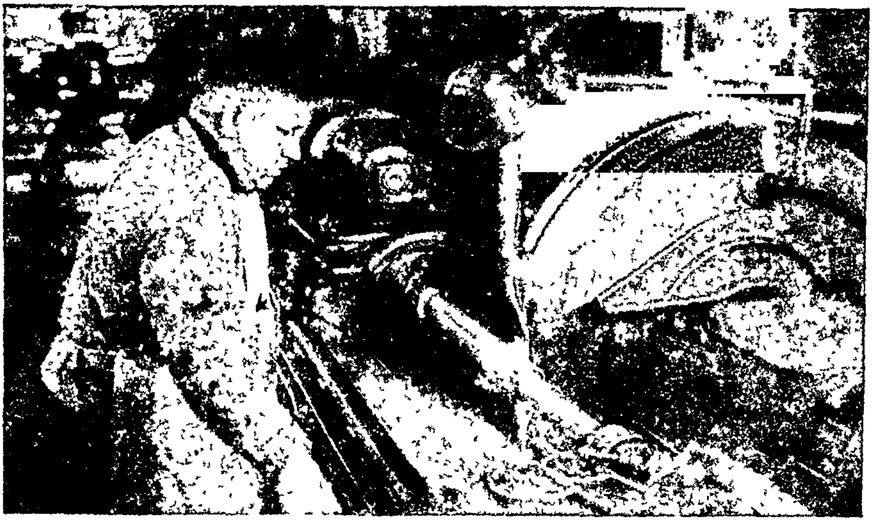


Fig. 5. Grinding. The grinding wheel (under the guard opposite the operator) is rotated against the shaft to be machined, which itself is turned at high speed The white liquid at the point of contact is a coolant.

Modern machine tools, as we have indicated, were first developed to an important degree of prominence about 175 years ago. This was when various European shops conceived the idea of driving metal-cutting tools by power and built the first successful, though very crude, working units.

Shortly thereafter, machine-tool building got under way in this country As early as the second quarter of the nineteenth century, certain manufacturers of firearms, textile machinery, water wheels, steam engines, locomotives, and similar equipment developed and built successful machine tools for their own use. Soon it was discovered that there was a growing demand for duplicates of these machine tools on the part of other manufacturing organizations which were springing up in increasing numbers, first on the Atlantic seaboard and later in the Middle West.

As machine-tool building looked like a profitable "side line," these early builders began to meet the demand, the firearms manufacturers generally

supplying what we today would classify as the smaller "precision" machinery, while builders of textile machinery, engines, and so forth met the demand for heavier types of machine tools. This led by natural evolution to the manufacture of machine tools as a separate industry. That will explain why the firearm centers of Hartford, Conn., Windsor, Vt., and Providence, R. I., won early supremacy in precision machinery, while textile-machinery centers like Manchester and Nashua, N. H., and Lowell, Mass., and Philadelphia with its textile machinery and locomotives, became noted for their heavy machine tools at an early date.

Very early in this period of expansion, the new plants gradually found their way west to such cities as Rochester, N. Y., Cleveland and Cincinnati. O., Rockford, Ill., and Milwaukee, Wis., so that today the industry is fairly well distributed in the northern part of the country between the Mississippi River and the Atlantic Coast.

In addition to these and the New England cities, other important machine-tool centers today are Buffalo, Toledo, Detroit, Indianapolis, and Chicago. A few machine-tool plants are also located below the Ohio and west of the Mississippi. Aside from accessibility to consuming markets, one of the most important factors which have influenced the location of plants is, of course, the availability of cast iron and steel and of skilled mechanics.

A very complete history of the personalities and companies involved in the growth and development of the industry will be found in Chapter XXVI of the first edition of this book, published in 1932, to which readers are referred for additional details.

Interchangeable manufacture. The outstanding fact about machine tools is that, by producing an endless number of identical parts, they make possible what is known as "interchangeable manufacture," or what is known in Europe as "the American system." Interchangeable manufacture, in turn, makes possible mass production.

Back only a century and a half ago there was no such thing as interchangeable manufacture. Everything mechanical, like locks and hinges and guns and printing presses, had to be made one at a time. In making a knife, for example, the metalworker would first make a blade, then a handle to fit that particular blade. If he made two blades and two handles at one time, it would be very unlikely that blade number 1 would fit handle number 2.

There can be no doubt that the real "patron saint" of the interchangeable system of manufacturing was that great American inventor Eli Whitney, whose popular fame rests almost entirely upon his widely publicized invention of the cotton gin. Whitney's invention of the cotton gin would have an important place in the story of machine tools if for no other reason than that it made cotton available cheaply and in large quantities, and this in turn created a demand for a vast amount of textile machinery, the building of which required more and better machine tools.

But aside from that, the cotton gin played another role in the story of machine tools. It virtually brought Whitney to financial ruin through

years of effort to defend his cotton-gin patents against the raids of infringers. And this, strangely enough, was the powerful incentive for his activities in interchangeable manufacture, by which, it is pleasant to recall, Whitney recouped his fortune.

As early as 1717, an attempt was made in France to manufacture firearms on the interchangeable system; but as far as is known, this was a failure. At least, it did not develop to the point of production Of a second and much more elaborate effort by French gunsmiths, made in 1785, there is conclusive evidence in an interesting contemporary letter from Thomas Jefferson (then United States Minister to France) to John Jay. This letter, dated August 30, 1785, contains the following statement:

> An improvement is made here in the construction of muskets, which it may be interesting to Congress to know, should they at any time propose to procure any. It consists in the making every part of them so exactly alike, that what belongs to any one, may be used for every musket in the magazine. . . . Supposing it might be useful in the United States, I went to the workman. He presented me the parts of fifty locks taken to pieces, and arranged in compartments. I put several together myself, taking pieces at hazard as they came to hand, and they fitted in the most perfect manner. The advantages of this, when arms need repair, are evident"

It appears, then, that Thomas Jefferson was responsible for transplanting the "interchangeable idea" from France to America.

Mass production, which has revolutionized the world, was born several years later, when Whitney duplicated the astonishing feat described by Jefferson in order to get an important United States Government contract for the manufacture of muskets.

Today parts are manufactured so accurately that an assemblyman in an automobile plant can pick up any one of millions of engine valves, simply slip it into any valve sleeve of any engine block coming down the line, and immediately forget about it. No individual fitting, no filing or scraping are required. The parts have already been fitted much more accurately than they could possibly be fitted by hand The valves and the holes they fit into will not vary by more than a fraction of one thousandth of an inch. This is less than half the thickness of a human hair.

Before the development of machine tools, manufacturing was dependent directly upon the ability of the individual artisan, upon his skill with his hands. Today such highly skilled handwork is built into machine tools, and machine-tool operators reproduce this skill over and over again by simply pushing levers and buttons and turning wheels.

Thus it is possible for thousands of men and women with just average skill and ability to produce parts and put them together to form such an intricate mechanism as a telephone (made up of some 240 individual parts) or a vacuum cleaner (750 parts) or an automobile (32,000 parts). When put together this way, these mechanisms not only work but, it should be pointed out, are so inexpensive that the average person can afford to buy them

Jigs, fixtures, and gauges. In order to appreciate what Whitney had to do in setting up his early musket plant, it must be remembered that not only was the technique of making jigs, fixtures, and gauges almost entirely new but also that every machine tool for making these jigs, fixtures, and gauges—as well as for the actual gun-manufacturing operations—had to be designed to a considerable extent, and certainly all had to be built, by Whitney himself. Furthermore, a large body of workmen (he started out with a force of 60 men) had to be trained in the new system. More than that, there were in those days few, if any, mechanical standards, and these had to be created "out of whole cloth" as the need for them arose It is not surprising that it was about 2 years before the project really got underway from a production standpoint.

Jigs, fixtures, and gauges, therefore, deserve some explanation at this point. They are vital to interchangeable manufacturing and also can almost be considered as components of machine tools, so closely are they related to them. It is significant that jigs, fixtures, and gauges today remain in their basic features essentially as originally developed a century and a half ago.

Briefly, a jig is a combination work-holding and tool-guiding device used in connection with drilling machines principally, by means of which a machining operation is performed on successive pieces of work to a uniform degree of accuracy. The skill of the toolmaker who makes the jig is embodied in the jig, and this skill is transferred to every piece of work machined in it. Thus no great skill is required of the machine-tool operator himself.

One of the simplest type jigs is an open-end cast-iron or steel box into which holes have been drilled at desired locations. The work pieces to be drilled are put into this box one at a time, the box is clamped on the drill press, and the operator simply feeds the drill down through the holes already cut in the work-holding box. Thus he produces holes in the work piece at just exactly the desired locations. Obviously, no responsibility for accuracy falls on the operator, whose operations simply are: inserting and clamping the work, feeding down and withdrawing the drill, and unclamping and removing the work.

A fixture is a work-locating and work-holding device which, like the jig, sometimes embodies tool-locating means. A fixture usually is like a vise or a chuck, and it frequently has finished reference surfaces for locating tool cuts on surfaces in various planes. As this last statement indicates, fixtures most generally are associated with milling machines, planers, shapers, slotters, boring mills, and various other "surfacing" types of machine tools. Actually, the distinction between jigs and fixtures is rather vague in the minds of many mechanics, and the names are apt to be used together or interchangeably.

The gauge generally is understood to be a precision measuring device designed for a specific purpose, as, for example, checking the length of a steel rod machined at both ends. A simple gauge for that purpose would be a U-shaped piece of steel, hardened to minimize wear, with the distance between the inside faces of the prongs of the U stoned down

to the exact length required of the rods to be manufactured. Gauging would be accomplished by trying the rods between the prongs.

While gauges commonly are associated with inspection work rather than with production, actually they are used in production work and in the setting of cutting tools in machine tools. Certain modern machine tools have built-in gauges. From the simple gauges of Eli Whitney's day, which used to be fitted to the parts of a "master gun" (as also were the jigs and fixtures), this art has advanced tremendously in the degree of accuracy attained and in the adaptation of "laboratory physics" to machine-shop practice—advanced even to the application of light waves to making measurements in millionths of an inch.

All except the simplest kind of jigs and fixtures—as well as many special gauges—must actually be designed around the particular parts with which they are associated. They are very expensive to make, requiring the services of special designers and highly skilled toolmakers, as well as the finest materials and toolmaking equipment. It is by no means unusual for expenditures to run as high as $100,000 for jigs, fixtures, gauges, and certain other special tools in preparation for the manufacture of such a thing as a new model washing machine.

Life of machine tools. Like everything else, machine tools wear out. A very fine, accurate tool-room lathe which has been in use in a tool room for 10 years is no longer suitable at the end of that period for precision work, in spite of occasional overhauling. It might still be acceptable in manufacturing departments where work need not be held to such close tolerances or produced with a very fine finish. After a few years more, it would still be an excellent tool for a garage mechanic, whose occasional requirements are not exacting. Its productive life is long, but the machine tool becomes less accurate as it grows old in service.

Obsolescence reduces the economic life of a machine tool to a fraction of its physical life. Our rapid development as an industrial nation and the improvement in our standard of living are largely due to our willingness to discard a tool as soon as we can find a better one, whether the first is worn out or not.

It is not economical to keep an old-style machine tool in operation when a new tool offers faster production, a better finish, a higher degree of accuracy, and perhaps greater safety to the operator as well. It is unusual for any design of machine tool to remain standard for more than about 7 years. The development of a newer and better machine of that type is likely to make it obsolete by that time.

Development of new designs. Machine-tool builders are constantly engaged in the process of research, development, and invention. This process is retarded only when they are extremely busy with customers' orders. As business declines, it gets proportionately more attention.

The trend of development in the design and manufacture of machine tools has been toward the use of better materials—such as the modern alloy steels—and toward greater weight, because it has been found that this tends to eliminate vibration, give longer life to the cutting tool, and promote greater accuracy.

There have been refinements in every part of the machine. Gear teeth today are usually cut from alloy steel, which is heat-treated. The teeth are then ground, shaved, or lapped after heat-treating to remove any distortion that might be caused by the heat treatment. The shaving of gears is now carried on to extremely close limits and is a satisfactory alternative method of manufacturing them. Shafts that run at high speeds are supported by antifriction bearings, and practically all of the moving parts of modern machine tools operate in a flood of filtered oil. A generous flow of coolant over the cutting tool prolongs its life and accuracy.

Recently, there has been a decided trend toward the simplification of the outline of the machine, so that it can be kept clean more easily. Sharp corners, which cause trouble in the foundry, are largely eliminated; moving parts are enclosed to protect them against damage. Incidentally, the operator is protected against injury and his work is simplified.

The electrical drive of machine tools, which came into common use about 30 years ago, not only increases general plant efficiency by eliminating the forests of belts which used to add to overhead expense and cut down the light in machine shops but also permits the placing of machine tools in the most effective operating positions, since line and countershafts need no longer be considered.

Originally, unit drive was from one motor. Subdivisions of the machine, such as the feed mechanism, were connected to the main drive by more or less complicated mechanical means. In the latest machine tools, however, unit drive has been subdivided electrically, so to speak, by the use of separate motors for distinct functions within the machine. Where necessary, these separate motors can be synchronized electrically to keep different sections of the machine in correct speed relation to each other.

Electrical control, the development of which has paralleled that of electrical drives, has done more than anything else to promote the grouping of various controls at one or more central stations most convenient to the operator. Machines which formerly were controlled by various levers and knobs whose location here, there, and everywhere over the machine were dictated by contingencies of mechanical design, rather than by the anatomy of the operator and by convenience in operating, now are controlled by one or more neat push-button stations, strategically located from the standpoint of efficient use.

In recent years, there has also been a marked development in hydraulically operated machinery. This is by no means a solution to all machine-tool problems, but the hydraulic operation of certain machine parts has proven very satisfactory on certain types of equipment.

There has been a constant effort on the part of the machine-tool builder toward the standardization of small tools and attachments, spindle noses, chucks, and other parts, and this process is still going on. It is an economy for customers, who do not have to carry so large a line of small tools and attachments in stock. But the process involves a great many difficulties and is a matter of development over a period of years.

In general, the development of machine tools has progressively made

it easier for the operator to produce good work and made it possible for the employer to use men of less skill in the operation of the machine, at the same time securing greater output and a higher degree of accuracy. In other words, skill is built into machines, as we have said. To that extent the machines in themselves have become more complex and more expensive to build. On the other hand, it is now possible for operators without so long a period of training to produce accurate work in substantial quantity. This makes possible higher wages and shorter hours and better conditions of work, which is one of the great contributions that the machine-tool industry has made to the progress of our country.

Increased production. Although much credit for the American leadership in the production of machine tools must be given the machine-tool *builders* here, it is also true that, to a great extent, the demands of American-tool *users* for cutting down costs forced the sweeping improvements that have resulted. Metalworking plants in this country, especially in the automotive industry, in order to beat competition, have continually established more and more exacting requirements, and they have been willing to pay the cost of the improved designs required.

Results of these improvements in many ways have been phenomenal. Before 1900, chips were cut away from metal at the rate of about ¼ pound per minute. Today, a comparable figure is close to 20 pounds of chips per minute. At the same time, accuracy of the work has been increased at least tenfold It is possible to shave down a 2-inch bar of steel to a diameter of 1.85 inches, to take a typical example, almost 80 times faster today than at the turn of the century. And the size of the finished piece, instead of varying and being "out of round" a few hundredths of an inch, will be accurate to within a few thousandths of an inch.

This has been accomplished, as indicated in preceding paragraphs, by increasing the speed and power of the machines and making them more rigid. This, in turn, was achieved by a widespread use of antifriction bearings, better and more widespread use of alloy steels, more accurately finished parts, more carefully reinforced castings, better and heavier tools and attachments, better lubrication, and the development of radically new cutters of extreme hardness made of the carbides of such metals as tungsten, tantalum, and titanium.

These new cutter materials are sintered mechanical mixtures, rather than true alloys, and their hardness is comparable to that of the diamond. They are called "cemented" carbides. With these new cutters, which even today have not as yet reached their fullest use, machine tools can race through a chunk of steel at the rate of 300 or even 400 feet per minute. On soft metals, such as brass, bronze, and aluminum, they can go twice or three times as fast—almost as if the metal were so much soap—and still do an accurate job.

There are important reasons, of course, for machining parts very accurately. Obviously, individual parts must be accurately made if the whole unit of assembled parts is to work at all. Besides, the more accurately parts are made, the more easily and economically they can be put together. Ease of assembly, as we have seen, is what makes the

system of mass production so successful. Furthermore, the more accurately parts are made, the more smoothly they will operate. And the more smoothly moving parts operate, the longer they will last.

Methods of manufacture. In the machine-tool industry, where a typical order calls for just one machine, it is obvious that machines cannot be put through in very large lots. It is one of the paradoxes of American industry that the manufacturer of equipment for mass production cannot use mass-production methods on a grand scale in his own plant.

Wherever possible, however, the industry manufactures small elements like gears, pins, shafts, and levers in quantity and puts them into stock These small parts are then drawn out for manufacture into subassemblies, which again are put in stock. These, in turn, are drawn out for the main assembly as fast as the base, or bed, of the machine comes to the assembly floor. The very extensive use of gauges, jigs, and fixtures in machine-tool plants affords complete interchangeability of parts Every operation is followed by inspection in order to detect errors at their source and to avoid further work on spoiled parts.

To obtain further economies certain parts are made interchangeable over a range of sizes. Thus one headstock may serve for lathes of various lengths, and the same hydraulic feed system may be employed on several sizes of lathes.

In some divisions of the industry, special machines are developed for unusual needs by applying standard units or heads to a welded steel base. The use of welded steel eliminates the cost of the wooden pattern required when castings are used and makes possible great flexibility in the arrangement of the machine.

Specialization. While there is no monopoly in the machine-tool industry, the tendency in general is for each company to specialize on one type of machine and develop it to a high degree. In years past, any machine-tool builder would build any type of machine tool that the customer wanted to buy, but a company which tried to do that today would face in every division of its work the competition of a group of specialists, which would make successful operation practically impossible

Competition between machine-tool builders is very keen, not only between builders of the same type of machine but also because, on many parts, various types of machines can do the work. and it is a close question as to what method of manufacture would be best.

The purchaser's decision is almost always based on economy in the operation of the machine tool, the accuracy required, and the quantity of production that the machines will yield under normal conditions.

Management and personnel. Most machine-tool companies are owner-managed. They were started by one man or a small group of men who have been brought up in the business, who have spent their lives in it, and who are thoroughly familiar with the varied problems involved, whether it be in purchasing, sales. design, or management. Some plants are now being operated by the third and fourth generations of the founders' own families.

By its very nature, the machine-tool industry requires personnel of the finest type. Its engineering staffs are confronted repeatedly with crucial problems which demand a high order of skill and training There is no industry in which designing genius and the ability to build efficiency and sustained performance into machines and equipment is of greater importance The service rendered by the machine tools of today is ample evidence of the degree to which these groups have fulfilled their responsibilities.

The first concern of the machine-tool industry is accuracy. It is obvious, therefore, that workers whose productive time is devoted to accurate performance must be men of a superior type—intelligent, thorough, dependable, and orderly. To these attributes must be added skill and training.

It is a traditional policy in the industry to develop mechanics from apprentices or so-called "learners." Apprentices are youngsters with a high-school background who are put through a definite, well-developed course They are shifted from department to department, with the purpose of developing all-around men from whom foremen, superintendents, works managers, demonstrators, and salesmen can be selected. The learners are usually men of more mature years who are trained to run some particular machine and who therefore become machine operators, or "specialists."

Machine-tool mechanics constitute a group of workers which can hardly be matched in any other industry. The exacting demands for precision and performance in machine tools call forth handicraft of a superior order, the hands and brains of the builders are thus developed to a high degree, and pride in work is a major attribute of all these craftsmen who have given extended service to their industry.

The large percentage of men in or past middle age or men with many years of service in machine-tool plants refutes the contention that there is no place in industry for men over forty.

The machine-tool worker is not of a roving disposition. Many plants have fostered housing plans, and the great majority of the good workmen own their own homes, live in communities together, and take pride in good citizenship.

Working conditions and problems. Machine-tool builders have always maintained a policy of paying wages which compare favorably with those paid in any other industry. Working hours are reasonable, and the cleanliness, sanitation, and lighting of the plants conform to the highest modern standards, as might be expected in an industry in which accuracy is a first consideration. Under normal conditions, therefore, the turnover rate of labor is unusually low.

Extreme variations in the demand for machine tools, however, create a very difficult personnel problem. The gradual development of higher speed and refinements in the precision of the work make it increasingly important to have highly skilled mechanics available. Under favorable conditions, the energies of the industry are directed to this end through intensive training.

When business falls off sharply, however, the machine-tool builder maintains, if he possibly can afford to do so, a nucleus of his older, more experienced men; but it is sometimes hard for him to retain apprentices and learners. After a depression, when business improves, it is very difficult to get back the men who have been released. Their training makes them desirable for a host of other activities, such as operating machine tools in other metalworking plants, repairing automobiles and trucks, and similar types of industrial activity. In that way, the machine-tool industry has served as a training ground for other industries.

Variations in demand. In addition to creating a serious personnel problem, extreme variations in the demand for machine tools seriously affect the industry in other ways.

All durable-goods industries are subjected to extreme variations in demand for their products. But because the machine-tool industry ultimately supplies all the others, this basic industry is probably affected more than any other. When building up, the demand has a tendency to go to a higher extreme in the machine-tool industry than in the others; and when the demand drops off, it has a tendency to drop off to a proportionately lower level.

When, after a depression, people resume normal buying, the increased business is quickly felt by clothing and automobile manufacturers, by the building trades, the transportation lines, and other industries. The improvement in these industries spells new business for the textile mills, the building-supply manufacturers. the railroads, and bus and air-line equipment manufacturers. It puts the production facilities of the country to work again, and this in turn develops the demand for new and improved machinery with which to satisfy the reviving markets.

But the machine-tool builders are a step further removed from this picture. They must wait until the production equipment manufacturers feel that *their* new business, in turn, warrants the buying of new equipment for *their* shops.

Of course, machine-tool builders also supply many consumer-goods manufacturers directly. But the total effect on the machine-tool industry, as the country comes out of a depression, is one of suppressed buying at first and then suddenly a tremendous demand.

In the reverse way, the same thing happens when business in general starts to fall off. Just as soon as manufacturers anticipate a falling off of business, the first thing they do is to cut off the buying of new machinery. In order to save cash for the lean days ahead, they get along with their existing equipment. And they do not buy new equipment again until they feel the business trend is definitely reversed and they are sure that the upward trend will continue for some time to come. For these reasons, the machine-tool industry is always one of the first to feel the effect of a business recession and one of the last to feel the effect of a business upturn.

Machine-tool builders therefore must manage their business on what might be termed a "peak-to-peak" basis. They must accumulate enough reserves from one good period to carry them through to the next.

However, in the interest of self-preservation, if for no other reason, manufacturers must be continually improving their product. There can be *no tapering off of engineering development work simply because*, during a depression period, there are few current orders. As a matter of fact, just the reverse is true. There is good reason to push research and experimental work more than ever. For as business improves and the market for machine tools slowly recovers, there will be an opportunity to stimulate this market to greater volume by the offer of vastly improved and more productive equipment.

Machines and the Standard of Living

Since machines are such an important force in our lives today, no discussion of machine tools would be complete without a consideration of their social effect. Great industrial development has revolutionized living conditions, and as we have seen, machine tools are the "master tools" of industry.

In this connection the most important thing about machines is that they enable us to multiply the amount of our day's work. They make it possible for us to turn out many hundreds of times as much work as we could possibly produce in the same time by hand. Machines are, therefore, first of all labor-saving devices. Machines are means by which electricity and steam and metal can be made to do the work which formerly had to be done by human muscle.

Not so many years ago, for example, people threshed grain with hand flails. They drew water out of wells by hand and washed clothes by the back-breaking process of beating or rubbing them. But today, modern threshing machines and electric pumps and washing machines do these jobs for us. In this way machines have eliminated a large part of the complete physical exhaustion which, not so many years ago, was the normal daily experience of many American people.

But machines are more than simply labor-saving devices. By making possible interchangeable manufacture and mass production, machines so reduce cost of manufacture that comforts and conveniences otherwise limited only to the wealthy are made available to all.

Everyone is familiar with thousands of instances of this kind. Transportation, for example, is no longer a luxury. Today millions of people own automobiles that take them quickly and inexpensively anywhere they want to go Today the best in music is available to everyone, not only to those who can afford high-priced opera and concert tickets. Today, by means of photography, anyone can have his likeness reproduced on paper, not only those who can afford to hire portrait painters.

But besides putting luxuries into the reach of the average man, machines go a step further. They create entirely new comforts and conveniences unknown and undreamed of yesterday even by kings. Electric lights, iceless refrigeration, moving pictures, typewriters, telephones—all are common products of machines unknown not so many

years ago before the development of machine tools. The list could be multiplied, of course, a thousand times.

Machines and Jobs

Much as machines have contributed to improving the standard of living, however, they have always been under attack. For the very reason that machines can turn out more work than can possibly be done by hand, and improved machines can turn out even more work than the earlier designs they replace, people have always feared machines and not infrequently have attempted to prevent their use.

Even before the development of machine tools, as long ago as 1661, when a loom was set up in Danzig that could weave from four to six webs at a time without much more than incidental human aid, the authorities prohibited its use and killed the inventor

The word "sabotage" comes from the French word "sabot," which means wooden shoe. The story is that early factory workers who objected to the introduction of power-weaving machines wrecked them by throwing their wooden shoes into the new equipment.

Undeniably, in some cases where machinery is introduced there is some temporary technological unemployment, and adjustments have to be made. These adjustments are made in this way: Machinery enables the manufacturer to offer a better product at a lower price Because of the lower price, more people can buy the product. This increases volume, and an increase in volume starts a wave of reëmployment which, in many notable instances, has meant the creation of many times the jobs initially eliminated.

In Paris a few hundred years ago, for example, the quill penmen rioted because printing machinery was introduced to replace hand copying. But printing presses so reduced the cost of the written word that soon many more men were required in print shops than had been employed as penmen. Again in the same industry in America, about 50 years ago, hand typesetters fought the introduction of linotype machines. But linotypes helped make possible inexpensive books and magazines, and so increased the volume of printed matter that today there are five times as many employed in the printing industry as in 1890.

In many cases, the immediate adjustments that have to be made when new machinery is introduced create a considerable hardship on those directly affected. But that is the price of progress And not many people want to forego all the tremendous benefits of mechanization because of the comparatively few individuals who, as a result, must make employment readjustments. Not many wanted to forego the benefits of printing, for example, because of the comparatively few quill penmen and hand typesetters directly affected at the time by the necessary mechanization.

Instead of decreasing employment, there is plenty of evidence that mechanization increases employment. One need go no further than the United States Census figures to see how, over a period of years, as

mechanization has increased, jobs have increased. In 1870, 32.4 per cent of our population were gainfully employed. By 1900 this had risen to 38.3 per cent, and by 1930, first year of the depression, to 39.8 per cent. Census figures for 1940 are not available at this writing.

We have seen how mass production, by reducing cost of manufacture, makes available to all commodities that otherwise would be available only to the wealthy; also how further mechanization further reduces cost and thereby further widens the market. The result of this is, of course, increased employment. Let us look at a few typical examples.

In 1937, one could buy a much better electric refrigerator for $200 than he could one of the same size in 1927 for $400. According to the United States Census of Manufactures, the electric-refrigeration industry employed 11,000 men in 1927 and 50,500 men in 1937, the year for which the latest figures are available.

In 1937, one could buy a much better automobile for $900 than he could buy in 1927 for $1,200. The automobile industry is one of the most highly mechanized of all. Yet employment rose from 370,000 in 1927 to 517,000 in 1937.

In 1937, one could buy a much better radio for $40 than he could buy in 1927 for $150. Radio is a perfect example of a purely mechanical development. There were so few people employed in the industry in 1927 that they were not listed in *Census of Manufactures Reports*, whereas, in 1937 the industry employed over 48,000 people.

In the same way, one could go on and on with other commodities. It is estimated that today no less than one out of every three persons employed owes his job to an industry that did not even exist in his grandfather's day. One need only glance over the other chapters in this book to find these industries and the millions of jobs they have created.

Machines and National Defense

It is truly unfortunate that the products of man's great inventive genius and mechanical skill can be used for destructive as well as constructive purposes, but so it is. The same equipment that can machine a water faucet to help solve man's age-old problem of getting water into his house can also be used to machine a shell. And the same trucks and radios and canned foods which have freed man of drudgery that since earliest times has marked his living can also be used to wage war. Machine tools which are vitally important in peacetime are therefore equally important in preparing for war.

In times of national emergency, the service of the machine-tool industry in supplying equipment is twofold: (1) to government establishments, such as arsenals and navy yards; and (2) to the metalworking industries mobilized by the government for the production of tanks, airplanes, guns, and other munitions.

All these requirements must be met, along with those of manufacturers engaged in normal peacetime pursuits as well. The machine-tool industry in times of emergency, therefore, is faced with the very difficult prob-

lem of furnishing a tremendously increased volume of equipment. This requires sizable increases in plant facilities and the training of new skilled workers to operate new machines and existing machines for second- and third-shift operation. Every resource of the machine-tool industry always has been pledged to the production of essential equipment for preparedness, and it has always accepted its responsibility in this connection.

From the standpoint of business and profit, however, the progress and prosperity of the industry are part and parcel of the normal, peacetime progress and prosperity of the whole country. The industry is dedicated to the arts of peace; its major objective is the production of equipment which makes for better, happier living for all. It is the foundation on which rest the giant industries of America that have made possible the highest standard of living that the world has ever known.

27

The Electrical Industry

Introduction

The electrical manufacturing industry had its inception in the vision, courage, and resourcefulness of a few pioneers; it grew because it supplied something that lightened human toil and added to human happiness. The products of this industry have marvelously changed human existence.

We press a button, and we turn night into day; we throw a switch, and the electric motor does our work for us. There is scarcely a thing that we have or do into which electricity does not in some way enter. It has grown to be a great industry, yet its history spans a period of a little more than 50 years.

As a measure of its progress, let us compare the 1882 Edison "jumbo" generator in the Pearl Street Station, New York, with the 183,333 kilovolt-ampere Westinghouse generator installed in 1935 in the Richmond Station of the Philadelphia Electric Company. The former was the largest generator of its time in the first central station in America; the latter represents one of the largest single electrical machines ever built and involves many new developments necessitated by its size.

The early Edison generator produced direct current and was driven by a slow-speed steam engine using steam at 120 pounds pressure, the Richmond Station generator produces alternating current and is direct-driven by the most powerful tandem steam turbine built up to 1940, which uses steam at 375 pounds pressure and a temperature of 825 degrees F. The former produced its current at a low voltage, limiting transmission of the electrical energy to a distance of about 1 mile; this voltage and distance could not be increased. The latter produces current at 13,800 volts, permitting distribution within a 25-mile radius at the generated voltage; and this voltage can easily be raised, with transformers having an efficiency well over 99 per cent, to 220,000 volts or more, permitting transmission to points 200 or more miles away. The output of the earlier machine would light 1,200 16-candlepower incandescent lamps of its day; that of the latter would light an entire city of 1,000,000 persons. In the Pearl Street installation it took 8 pounds of coal to produce a kilowatt-hour at the terminals of the generator; the

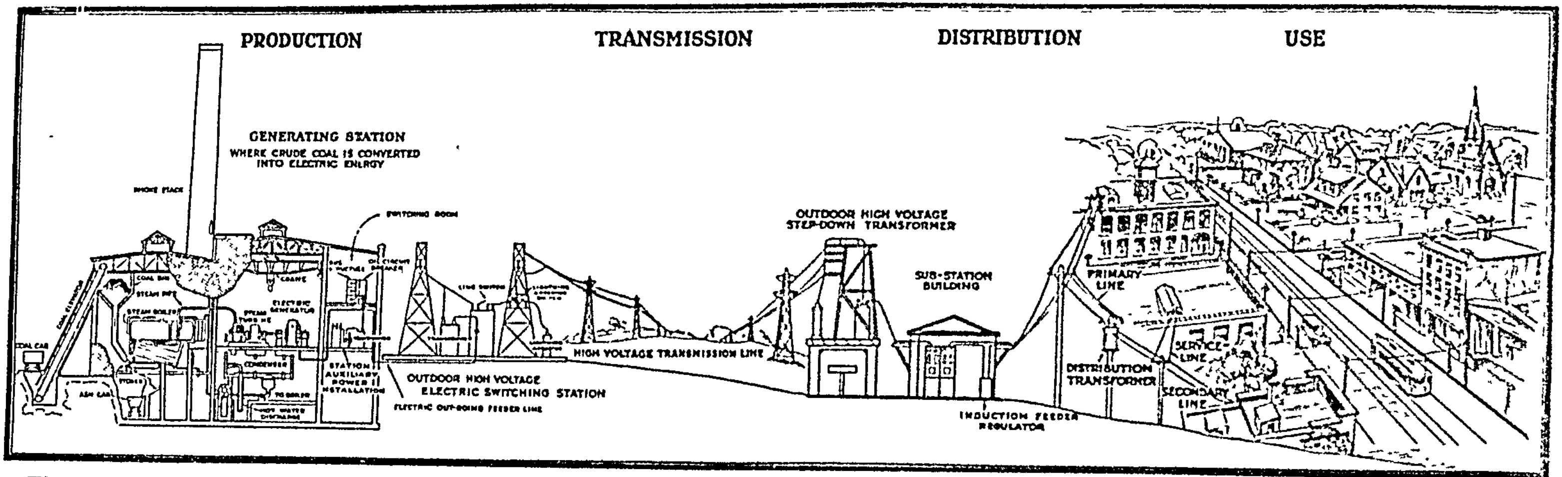


Fig. 1. Electricity. At the generating station, coal is elevated to overhead bins, from which it flows by gravity to revolving grates, on which it is burned Its heat turns water into high-pressure steam. The steam is piped to the turbine, which is a modern adaptation of the old-fashioned water wheel. The turbine revolves the electric generator which produces the electricity.

Alternating current at low voltage is generated in the station. For long-distance transmission, the voltage must be increased—sometimes to as high as 220,000 volts. This increase is accomplished by the "step-up" transformer, from which the electricity flows to the high-voltage transmission lines. These transmission lines carry the electricity to many communities, some of which are often many miles away.

However, the transmission lines carry the electricity at voltages which are too high for distribution over wires in streets and alleys of the communities served. Therefore, these lines are run to substations, where the voltage is reduced by "step-down" transformers.

At the substation the primary lines—the wires which extend to all parts of the community—have their terminals, and here they receive the electric energy for the homes, stores, offices, and industries of the community.

For economical distribution, the voltage in the primary lines is higher than the 110-volt, 60-cycle alternating current ordinarily used for lighting and the operation of small appliances. So, to lower the voltage further, distribution transformers are placed at convenient locations which are near the service lines. These lines carry the electricity into the homes and businesses of the customers.

Richmond Station machine produces a kilowatt hour with slightly less than 1 pound of coal.

The steam engine brought about an industrial revolution, but it was limited by the distance that power could be transmitted by belts and shafting. Electricity has furnished the means of transmitting the engine's energy long distances by a few wires, so that every city, village, and hamlet has power at the turn of a switch. Power is no longer "chained to the coal mine and steam engine."

Lighting

Lighting was the first application of electricity that caught the imagination in the early days of electrical development.[1]

The tallow candle had succeeded the grease lamp; the kerosene lamp the candle; and in thickly populated districts illuminating gas had superseded the kerosene lamp. But each left very much to be desired.

The arc lamp. The arc lamp was the first development in electric lighting. The writer of this article well remembers seeing one of the earliest arc lights shown by a traveling circus as a curiosity.

The early lamps were comparatively simple. They had two electrodes made of carbon in the form of rods. These were placed one above the other in a vertical position. The tips of the carbons were heated to incandescence by the current as an arc was drawn between the upper and lower carbons. These lamps were suitable for outdoor use only, and the carbons were consumed at such a rate that their life was short. One of the main problems of the arc-lighting system was to provide the current; Charles F. Brush of Cleveland, Ohio, one of the earliest pioneers in arc lighting, developed a generator to do this. Ingenious machines and lamps were also built by Waterhouse, Thompson-Houston, Hochauser, and others. All were operated on the constant-current principle because of the method of connecting many lamps in series. This method necessitated a generator for each set of lamps and the maximum attainable was about 60 lamps on one circuit. Later, when the alternating-current system had come into use, the lamp circuits were operated across the terminals of generators or transformers, with a number of circuits in parallel so that one generator furnished power for many circuits.

The incandescent lamp. The next step in the development of electric lighting was marked by the invention of the incandescent lamp, in which Thomas A. Edison took a leading part. This invention was the culmination of a long series of attempts to produce a source of light which would

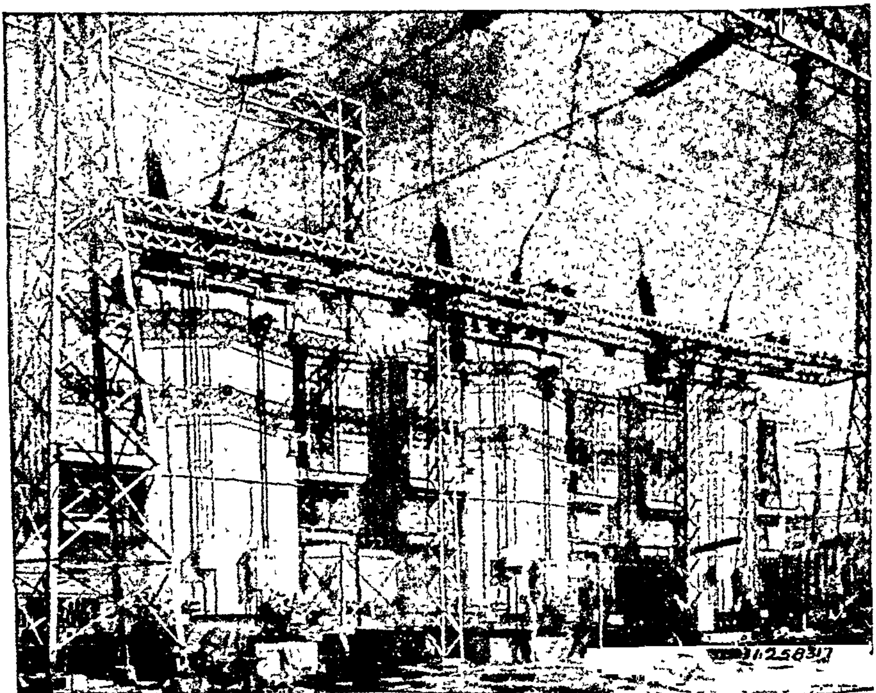
---

[1] Workmen digging on the Cornell University campus have unearthed two sections of rusty cast-iron pipe, which, on inspection, have been identified as part of the conduit laid in 1875 for the first outdoor electric-lighting system in the Western Hemisphere It extended from Morrill Hall to Sage Chapel

Though buried for 64 years, the pipe could still perform its original function. The copper wire in the center is protected by muslin strips and the surrounding space filled with beef tallow

be suitable for indoor use and could be connected in parallel across a source of low-voltage current.

About the middle of the nineteenth century various attempts were made to produce lamps by heating metals in vacuum. There were no results of commercial value because the melting points of the metals were too low; furthermore, the source of the electric current was chemical cells. When an adequate supply of electric current became available, through the development of the dynamo as a mechanical means of



Courtesy, Westinghouse Electric and Manufacturing Company

Fig. 2. Handlers of power These steel giants are three of the four autotransformers installed in 1939 by the Westinghouse Electric and Manufacturing Company on the power system of the city of Los Angeles. They are the largest ever built, cover a ground area of 300 square feet, and are 37 feet high. Rated at 65,000 kilovolt-amperes, they will step down power from the 275 kilovolt Boulder Dam lines to 138 kilovolts

producing it, special effort was put forth to produce a commercial incandescent lamp. Attention was then directed to carbon and the production of a filament from it. Edison, Sawyer, and Mann, in this country, and Swan and Stearn in Europe, produced carbon filaments of various raw materials.

To Edison belongs the credit of producing the first complete commercial lamp. It consisted of a carbon filament in a one-piece glass bulb from which the air was exhausted, and had platinum lead-in wires passing through the glass wall of the bulb. It will be interesting to quote

here from *Harper's Weekly* of January 3, 1880, the impression the incandescent lamp made on a newspaper writer of that day:

> Incredible as it may seem, a little piece of paper which you might blow away with a breath gives out the electric light It becomes no more affected, so far as destructibility is concerned, than platinum—one of the most infusible of metals—under the heat of a tallow candle. And from this piece of paper is obtained a pure and unadulterated light, a globe of sunshine, without deleterious gases, without noxious vapors, indifferent to wind or weather, requiring no matches to ignite, giving out no smoke or flame, possessing the uniformity and steadiness of the sun itself in clear weather, and withal a light cheaper in production than the cheapest oil.

Tungsten filament lamps. The carbon type of incandescent lamp, with various improvements such as metallized filaments, persisted for many years until the advent of the drawn-tungsten filament lamp, which practically superseded it, because of the much higher temperature at which the filament could be operated and the higher efficiency that resulted. The development of the processes of producing the drawn-tungsten wire came from the laboratories of the General Electric Company, as did also the gas-filled lamp, another improvement. The commercial production of the drawn-tungsten lamp lent a great impetus to all kinds of lighting; one special application that might be mentioned in passing was the lighting of the automobile, which would hardly have been possible without it.

Mercury vapor lamps. Incandescent lamps, as all other previous lighting units, produce light by heating some substance, such as carbon or a metal, to the point of incandescence. The higher the temperature became, the greater was the lighting efficiency, but most of the energy was wasted in the form of heat. The high-intensity mercury vapor lamp, first used commercially at the World's Fair in Chicago in 1934, was the first really successful example of a century-old attempt to produce light directly by electronic bombardment of gaseous atoms without passing the energy through an intermediate stage in the form of heat. The sodium vapor lamp, introduced about the same time, operates on the same general principle with a different type of gaseous conductor.

Both of these lamps have more than twice the illumination efficiency of the tungsten lamp. Both give approximately monochromatic light, with the advantage of providing greater visual acuity and the disadvantage of distorting colors. Despite this disadvantage, both of them, and particularly the mercury vapor lamp, are being extensively used for street lignting, tunnel lighting, and the illumination of factory areas and drafting rooms, where color distortion makes no particular difference. The mercury vapor lamp has the further advantage that when combined with an equal quantity of light from the ordinary Mazda lamps the resultant illumination is almost pure white.

Black light. The so-called "black light" consists of radiation that is mostly in the ultraviolet region beyond the range of visibility. The lamps can be screened so that there is no visible radiation.

Black light has been used to take photographs in absolute darkness. It is used to excite photoelectric cells in burglar-proofing vaults or buildings, the burglar not being able to see that he has interrupted a light beam which gives warning of his presence. It is also used to produce light from materials which have been coated with fluorescent substances, the object so treated being plainly visible in a room that is otherwise dark. Such effects have usually been decorative rather than utilitarian. A more practical application would be dark lighting of instrument panels for airplanes and motor cars. The pointers and numbers would be visible but there would be no other light to affect the operator's pupils, permitting maximum visibility.

The fluorescent lamp. In 1938, a new type of lamp made its appearance, using a principle of light generation several times more efficient than that of the incandescent filament, with the additional advantage of providing cool light. It is the fluorescent lamp, in which the electric energy creates a discharge across an atmosphere of ionized mercury vapor between electrodes at opposite ends of a long, slim tube. This discharge, extremely rich in invisible ultraviolet radiation, is transformed into visible radiation by means of special salts, called "phosphors," with which the inside walls of the tube are coated. Each phosphor produces its own characteristic color under ultraviolet radiation, making possible the production of light in any color including white. Depending on the phosphors used as generators of visible radiation, the comparative efficiencies of fluorescence over incandescence are as follows: blue, 60 times; green, 210; red, 5; white, approximately 3. Because of its elimination of the heat inherent in incandescent lamps and its ability to construct colors in beautiful combinations, the fluorescent lamp has already found many applications in home and commercial decorative lighting.

The Sterilamp. In a somewhat different field, Westinghouse recently introduced an even more revolutionary lamp under the trade name of Sterilamp, which produces ultraviolet radiation in the bactericidal band of 2,537 Angstrom units. Such lamps, operating on about one third the energy required by a 25-watt household lamp, are now installed in hospital operating rooms, where their radiation kills air-borne bacteria, in restaurants for keeping utensils germ-free, and in meat markets and bakeries for retarding mold formation on perishable goods. The Sterilamp is also one element in a patented process for the rapid tenderization of beef now being used by a number of meat packers and large food chain companies.

Early Commercial Stations

Edison stations pioneered in commercial lighting through the use of the direct-current system of current generation. Other companies, such as the United States Electric Lighting Company, the Sawyer-Mann Company, and others, also manufactured generators and lamps.

Economically, the direct-current system soon met with its limita-

tions because of the small transmission distance permitted by the necessarily low voltage. As a result, extension of lighting could not be secured by increasing the capacity of a powerhouse, but meant additional powerhouses An immediate help was the Edison three-wire system in which a double voltage was used across the two outside wires of the system, thus increasing the transmission distance. The gain, however, was relatively small.

It can be said of the direct-current system that it furnished a fairly satisfactory means of lighting but at an installation cost that limited its application to relatively small areas and prevented any extensive use of electric current for power purposes.

Beginnings of Alternating Current

Such was the situation when George Westinghouse entered the electrical manufacturing industry. In the early part of 1885 there came to his notice the invention by two young European engineers of a so-called secondary generator. This device, now known as a transformer, made it possible for the voltage of an alternating current to be raised for transmission, with a corresponding reduction in the amount of current transmitted, and then lowered to the utilization voltage at a distant point for distribution.

Mr Westinghouse perceived that, if this device should prove practicable, a way would be opened for the economical transmission of power over long distances He proceeded immediately to investigate this new scheme After satisfying himself of its possibilities, he acquired the American patent rights and began the development of the system. To him is due the credit of introducing alternating current into America. It has practically become the universal system for the generation and transmission of power, and various devices have been perfected for converting it into direct current in large or small quantities for those applications for which direct current is indispensable.

The Westinghouse Company

Mr. Westinghouse organized a company, incorporated in 1886, and gathered about him a number of young and capable engineers, who entered enthusiastically into the development of the new system and, through their inventions, left an indelible impress on the industry.

Among these engineers were William Stanley, whose chief accomplishment was the development of the transformer, and Oliver B. Shallenberger, whose outstanding work was the invention and production of the alternating-current induction meter, which supplied the new system with an accurate means of measuring the energy. Nicola Tesla contributed greatly to the new industry through his patents on the induction motor and polyphase system. Albert Schmid stamped his mechanical genius on the early apparatus designs. L B. Stillwell produced important regulating devices, and C. E. Skinner developed insulation materials

and methods of applying them. C. F. Scott, among other things, originated the Scott system of phase transformations. Francis Hodgkinson contributed much in the development of the steam turbine.

Benjamin G. Lamme, in the course of his unique career as an engineer, probably did more than any other one individual to develop those elements of the alternating-current system that have made it the universal system. He replaced the cut-and-try methods of building the electrical machines by methods of accurate calculation. His work included the commercial development of the squirrel-cage induction motor, the first practical streetcar motor, the main features of which are still in general use. He contributed greatly to the improvements in design and performance of both alternating- and direct-current generators. He developed almost single-handed the rotary converter for converting alternating current into direct current, overcoming numerous obstacles which many considered inherent defects. The single-phase system for steam-railroad electrification was also Lamme's.

During the time when all these inventions were being developed, Mr. Westinghouse was personally active in promoting and contributing to them.

The General Electric Company

The General Electric Company was organized in 1892, largely through the efforts of Charles A. Coffin, by combining the Edison General Electric Company with the Thompson-Houston Company. Mr. Coffin had previously become financially interested in the American Electric Company of New Britain, Connecticut, which was later merged with the Thompson-Houston Company of Lynn, Massachusetts. The chief products of these companies had been direct-current and arc-lighting systems. The Thompson-Houston Company actively took up the alternating-current system as its merits became known.

A number of outstanding men have been associated with the General Electric Company. Mr. Coffin excelled in his talent for organization and in the promotion of commercial activities. Elihu Thomson was an inventor and physicist of note. His original work was with arc-lighting systems; later he contributed to the alternating-current system. He invented the Thomson wattmeter and also electrical welding by the resistance method, which has found extensive use in industry. He was electrician and chief engineer of the General Electric Company for many years, and has made an impress on the industry in many ways.

Charles P. Steinmetz served the General Electric Company in a designing and consulting capacity. "His great usefulness was as a teacher, and apart from his books, his greatest work was to start the General Electric engineers upon the use of proper methods of calculation."

E. W. Rice came to General Electric through the Thompson-Houston Company, and became its chief engineer and finally its president. His wide technical knowledge was coupled with executive ability. Cummins C. Chesney was one of the pioneers of the industry, and has served his

company in engineering and managerial capacities, and the entire industry in outside organizations. Lewis T. Robinson was active in instrument development and in engineering laboratory work. W. F. Foster was an outstanding designer of electrical machines. H. M. Hobart has served as a designer and consulting engineer, and is an author of several books. W. L. Emmet took a considerable part in steam turbine development and ship propulsion.

The larger companies in the industry have continually expanded, as the size and variety of devices have increased, to meet the ever-expanding applications of electricity. The great number of different items that they are called on to manufacture, many in small quantities, introduces problems in production that are quite different from those existing where there are few items and large quantities In one of the largest companies of the electrical manufacturing industry there are over 300,000 individual sales items produced.

The Allis-Chalmers Company, next in size to the Westinghouse and General Electric, has been the result of the combination of several companies. There are also quite a number of other companies, most of which specialize in some particular line of products, such as transformers, insulators, motors, and control. They have contributed to a healthy competition, and have various improvements to their credit.

Pioneers

The electrical manufacturing industry in the United States, as we have it today, has exceeded the fondest expectations of the most optimistic visionary of the early days. Neither of the two outstanding leaders in the development of the electrical manufacturing industry, George Westinghouse and Charles A. Coffin, had previously been connected with electrical enterprises. The interests of Mr. Westinghouse had been in air brakes, train signaling, and natural gas transportation; his contacts were mostly with railroads. Mr. Coffin had been in the shoe manufacturing business; his contacts were mostly with the retail trade of that industry.

The foundation of Mr. Westinghouse's interest was the vision he had of the possibilities of the electrical transmission of power by alternating current. Mr. Coffin envisioned the financial possibilities of furnishing electrical equipment and promoting its use.

Growth By Consolidations

In the beginning the electrical manufacturing industry was composed of many small companies formed by individuals who developed the product, manufactured it under their own supervision, and promoted its sale. As the stronger companies grew they, in many cases, absorbed the smaller ones, until now the business is largely in the hands of a few large corporations. It thus comes about that in the more recent years developments have resulted from the coöperative efforts of many engineers and from

the combined enterprise of trained supervisors of artisans who work in immense factories equipped with elaborate automatic tools. Sales are carried on by a trained personnel scattered throughout a vast territory. All these are coördinated by a management group responsible to the stockholders through a board of directors.

Prominence of Engineering

Engineering has been a prominent feature of the activities of the electrical manufacturing industry since its beginning. The nature of its product seems to demand it. The industry is constantly reaching beyond the range of experience into larger units, broader fields, and special applications. Probably no better illustration of this can be found than the case of the initial Niagara Falls power development, the electrical apparatus of which was built by the Westinghouse Company. Previous to the Niagara installation, the only complete polyphase system of generation, transmission, and utilization of power on a commercial basis of any considerable size was the Westinghouse installation at the World's Fair in Chicago in 1893. The generators there were 1,000 horsepower. The Niagara generators were 5,000 horsepower and of a type never previously built; the water wheels were new and the switching equipment for controlling the electrical circuits from the generators was much beyond any previous experience. The Westinghouse engineers were called upon to solve many mechanical as well as electrical problems.

The effect of the successful performance of the Niagara Falls power plant was to stimulate the rapid increase of polyphase plants, both hydraulic and steam-driven, throughout the country. This plant has been characterized as the beginning of generation of electric power as a commodity. According to the 1930 United States Census figures, 25.5 per cent of the installed capacity of generating equipment for light and power in the United States was furnished by hydro units, 74.5 per cent by steam and internal-combustion units; of the latter 73.25 per cent were steam-driven and 1.25 per cent internal-combustion-driven.

Characteristics of the Industry

A characteristic of the electrical manufacturing industry has been the creation of apparatus before demand. Edison had to promote the use of his first lighting system. Westinghouse developed the polyphase system ahead of the demand.

> Two characteristics which were implanted in the electrical industry by the early leaders have been powerful factors in its amazing growth, namely constant research for better ways of doing things and instant readiness to scrap the old. In this respect the industry, I believe, has a record beyond that of any other. No charge of suppressing inventions, of delaying improvements stands against the electrical industry.[2]

---

[2] From an address delivered to students of Purdue University, April 22, 1925

Trends

While the large companies as a rule have their manufacturing plants concentrated in one location, the decided tendency is to locate plant extensions for certain lines of product in places that are more desirable from a raw material, shipment, labor, or other standpoint. Thus it happens that most of the large companies have plants at widely scattered points.

There is a noticeable tendency of the electrical manufacturing industry to go into the manufacture of complete pieces of apparatus of which the electrical equipment is but a part. Illustrations are refrigerators, ranges, and other household appliances.

Not only must an electrical manufacturing organization produce apparatus to meet the immediate requirements for its product, but it must anticipate new demands and develop new lines of products to maintain factory production.

Transportation

The electrical manufacturing industry has left its impress on transportation by furnishing means for propelling vehicles by electric power generated in stationary plants, sometimes at long distances from the point of use.

Work on applying electricity to traction was done as early as 1880 by Thomas A. Edison and Stephen D. Field, and in the same year Edison operated a small electric locomotive pulling a trail car. C. J. Van Depoele experimented in 1892-1893. His chief contribution was the underrunning trolley. Bentley and Knight initiated the use of an underground conduit for the conductors Professor Short began experiments in Denver in 1884. Daft about this time made an installation on the Union Passenger Railway in Baltimore, which was the first to operate regularly for fares.

First practical street-railway system. F. J. Sprague, who had begun work as early as 1881, installed in Richmond, Virginia, in 1888, what is generally regarded as the first of the modern street-railway systems. It had an overhead trolley line over the center of the track, reinforced by a main feeder conductor. It was operated at 450 volts. Current was collected by an underrunning contact. Seven and a half horsepower, series-wound motors were connected to the driving axles by double reduction gears, and a series-parallel control was used. Great credit is due Mr. Sprague for his pioneer work in this development. Following his inventions, numerous installations throughout the country rapidly replaced horse-drawn cars.

Early manufacturers of street-railway equipment. The early installations were made largely by the Sprague Company and the Thompson-Houston Company, which had absorbed the Van Depoele interests. The Sprague Company was absorbed in 1890 by the Edison General Electric

Company. Westinghouse had begun the manufacture of car equipment in 1889.

Up to this time, all the motor equipments had been double reduction and of an open type. This arrangement was very noisy and difficult to maintain, because the motors were exposed to weather conditions. Westinghouse motors were the first ones to have their gears inclosed in gear cases. In 1890 Lamme, of the Westinghouse Company, originated a single-reduction gear design which was quite completely enclosed. This was put on the market in 1891 and revolutionized traction practice. The main features of this motor have persisted to the present time.

Besides the development of apparatus for the cars themselves, the perfection of devices for changing the alternating current, as universally generated, into the direct current required for the street-railway circuits has been a large element in the success of street-railway transportation. In particular, the rotary converters have been an outstanding development with results that are largely the personal accomplishment of Lamme. The development of the mercury-arc rectifier, without moving parts, has received much attention in recent years. Methods of automatic operation of substations whereby they are put into operation when a load comes on, and put out of operation when the load goes off, have come into vogue.

Electrical street-railway transportation, both surface and underground, has come into very wide use with modifications which have been refinements rather than radical changes. This development has brought about the rapid transportation which has made possible immense concentration of population into cities, and has greatly changed living conditions.

Railroad electrification. The electrical manufacturing industry has contributed much to heavy traction, as in steam railroad electrification. The steam plants are taken off the locomotives and concentrated in a stationary powerhouse, and are replaced by electric motors which receive their energy from the power house through overhead conductors or a third rail alongside the tracks. Electric drive increases the track capacity, contributes greatly to passenger comfort, and improves fuel economy.

Railroad electrification has received a great impetus in recent years because of the concentration of populations and the need of increased transportation facilities, conditions which it admirably meets.

Two important systems of electrification. Two main systems of utilization of electricity on locomotives in rail transportation have persisted. One of these, originated by Westinghouse, uses alternating current; the other uses direct current.

The alternating-current systems in this country normally use 12,000 volt trolleys, although other voltages are perfectly feasible. The direct-current systems vary from 600 volts to 3,000 volts on the trolley.

The alternating-current system In the alternating-current system the current, reduced in voltage by passing through transformers carried on the locomotive, is used direct on the motors. The locomotive speed is controlled by varying the voltage delivered by the transformers. In this system, the motors have an inherent variable-speed characteristic; the heavier the load the slower the speed. In a modification of this, where

constant-speed motors are desired for certain installations, the locomotive carries a phase changer which changes the single-phase current received from the trolley into polyphase current for the motors. One distinctive advantage of constant-speed driving motors is that they can be used for regenerative braking on grades by operating as generators and pumping energy back into the line. Thus a train going down-grade is made to assist another train going up-grade.

Direct-current systems. In one type of the direct-current system, the motors are supplied with direct current obtained by converting the alternating current received from the trolley to direct current by means of a rectifier device carried by the locomotive. The speed control is obtained by varying the direct-current voltage applied to the motors. In the other type of direct-current system, the current supplied to the trolley conductor is direct current obtained from the alternating-current distribution system by rectifying substations placed at intervals along the right of way. The alternating-current trolley has a distinctive advantage in that its capacity can be increased without changing the conductor by increasing the voltage. Locomotives of the first type have no present-day significance.

Generation

The electrical manufacturing industry often has been forced into the development of apparatus not of an electrical nature because the advancement of the electrical art was dependent upon such development. Such a case, revolutionary in nature, was the steam turbine and along with it the electrical part, the turbine generator. The steam turbine made possible the building of very much larger capacity units with the attendant advantages.

Introduction of the steam turbine. Previous to the development of the turbine units, the largest units built, such as the 6,000-kilowatt Interborough Rapid Transit sets, were slow-speed machines driven by the Corliss type of steam engine. The physical size, weight, cost, and floor space required indicated that the possibilities of further development along this line were very limited. George Westinghouse sensed the possibilities of the turbine type of steam engine. This had a rotating element instead of reciprocating parts, and the exhaust openings were not limited in size as in the reciprocating engine, making possible not only greater expansion of the steam but also greater volumes. An important advantage lay in the immense increase in speeds possible. Sir Charles Parsons had done pioneer work on steam turbines and had built them in small sizes. In 1896 Mr. Westinghouse secured from him the patent rights for the United States. The work initiated soon after that by the Westinghouse Machine Company on the turbines, and by the Westinghouse Electric & Manufacturing Company on the generators, was the beginning in the United States of the active development of this type of apparatus. The first noteworthy installation in this country was made in 1899, when three 400-kilowatt Westinghouse turbine-generator units were installed

in the plant of the Westinghouse Air Brake Company, Wilmerding, Pennsylvania, where they continued in operation for 25 years. This was followed in 1900 by the historic installation of a 2,000-kilowatt set in the plant of the Hartford Electric Light Company, Hartford, Connecticut, the largest capacity unit in the world at that time. Shortly after the Westinghouse installation at Hartford, the General Electric Company began the construction of two 5,000-kilowatt vertical units for the Commonwealth Edison Company, of Chicago. From this time on, the development of the turbine type of units was very rapid; the sizes were increased rapidly, and the performances improved. Both Westinghouse and General Electric were leaders in this field; the Allis-Chalmers followed later on. A number of smaller companies also engaged in making moderate-sized turbines.

Demand for larger installation. The growth of our cities and industrial centers has created a need on the part of the electrical lighting and power companies for larger and larger concentrations of power-producing apparatus, and this in turn has resulted in a demand for larger individual units. It is interesting to note that today units of more than 165,000-kilowatt output are being designed and built.

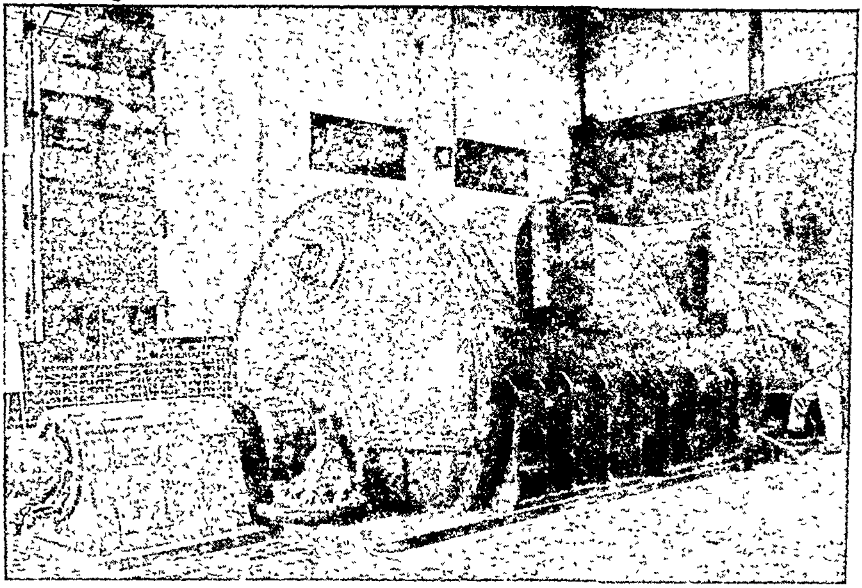
Coincident with the rapid increase in the sizes of the prime movers and the generators has come the need for greater steam-producing capacity in boilers, furnaces, fuel-feeding apparatus, and condensing equipment, with corresponding developments of these. The stokers for fuel feeding have reached a high degree of refinement in fuel handling and automatic control. They, as well as the condensers, have in part been developed and manufactured by the electrical manufacturing industry.

Since 1930, in addition to higher steam conditions, superposition has appeared and the single unit 3,600-rpm. turbine has been greatly increased in capacity. The present type superposed turbine is the outgrowth of the availability of the high-pressure steam generator. A central station having four 1920 vintage low-pressure turbines could, for example, install high-pressure steam generators and a superposed turbine through which the total steam would flow on its way to the four old units. Such an arrangement is attractive for three reasons: (1) the station capacity is increased about 60 per cent; (2) the fuel economy of the new arrangement is improved about 40 per cent; and (3) the capital investment in the old turbines is protected for an indefinite period.

This trend for greater economy was climaxed with dramatic suddenness about 1935 by the purchase of several large superposition turbine generator sets. These superposed turbines pass from 1,000,000 to 1,500,000 pounds of steam per hour, at steam pressures of 1,200 to 1,500 pounds per square inch, a density five times as great as the low-pressure turbines with which they are in series. The steam temperature is 900 degrees F., a temperature high enough to cause the high-pressure blades of the turbine to operate at a dull-red heat.

Further application of the use of the steam turbine. Through the development of gearing, by which speeds are reduced to slow-speed requirements, the electrical manufacturing industry has extended the use of

the steam turbine to mechanical applications. One such application of importance is in ship propulsion, where both the steam turbine and the propeller are enabled to run at their most economical speeds. In the larger sizes, a very unique method of maintaining the alignment of the gears is the Melville-McAlpine device built by Westinghouse. Another ship-propulsion application is one where the steam turbines drive alternating-current generators which in turn furnish current to motors which drive the propeller shafts. This application is used for large vessels, such as battleships, and this type of drive is selected for certain advantages in the location of the equipment, in control, and in maneuverability. Direct-current generators are sometimes driven by steam turbines through reduction gears.



Courtesy, Westinghouse Electric and Manufacturing Company

FIG 3. Power-maker. This 35,000-kilowatt generator, manufactured at the East Pittsburgh works of the Westinghouse Electric & Manufacturing Company, is cooled by hydrogen Because it is less dense than air, hydrogen offers less resistance to rotating parts and increases the efficiency of the machine whose rotor revolves 3,600 times a minute

Contributions to Industry

The contributions of the electrical manufacturing industry to many other industries in the way of electrical drives and exact controls have revolutionized methods of production, with an increase in both quantity and quality of the product. Take, as examples, a machine-tool drive with a great range of speeds, and any desired speed at the push of a button; a paper machine with its seven or more groups of rolls running at differ-

ent speeds, and so regulated as to pass the paper through each at just the right speed; or an oil-well drill boring a 2-mile hole into the earth, a feat made possible by electric motor drive.

Steel production, in which the electric drive and control have been applied to practically every step from the mining of the ore to the fabricating of the steel into the frame of a skyscraper, is another illustration of the contributions which the electrical manufacturing industry has made to other industries. Strips of steel, from 54 to 72 inches in width, are now rolled in the modern continuous hot-strip mills at the rate of 2,100 feet a minute. To control these mill giants is as easy as driving an automobile.

"Statistics now show that there is an average of more than three horsepower of electrical energy, or the equivalent of thirty helpers, available for each American workman."[3] Earnings of the workman have been shown to be in proportion to the power per man.

The following data show that the production of electric energy per capita in 1920 was only 410 kilowatt-hours, as compared with 994 kilowatt-hours in 1939, or an increase of 142.4 per cent.[4]

Year	*Population*	*Kilowatt-Hours Per Capita*
1920	105,710,620	410
1925	114,867,141	572
1930	122,775,046	771
1935	127,521,000	772
1936	128,429,000	873
1937	129,257,000	943
1938	130,215,000	896
1939	131,179,000	994

Removing of Limitations

Probably no other industry has developed at critical times so many striking improvements that have removed limitations and broadened the application of its product as has the electrical industry.

In the beginning, the distribution of power by direct current was very limited. The alternating current extended the distribution range immensely. The high frequencies and single-phase circuits used initially in alternating current limited it to lighting. A lower frequency and polyphase broadened its application to both lighting and power. Several times, the distance alternating current could be transmitted was limited because the voltage could not be increased on account of insulation limitations, only to have these limitations removed by improved forms of insulation. At present the 288,000-volt line from Boulder Dam to Los Angeles represents the highest voltages in commercial use for the transmission of power, although voltages of 10,000,000 or more are used in test-

[3] *United States Department of Commerce Report* (Washington, D. C, October, 1929).

[4] Source: *Electric Power Statistics*, Federal Power Commission (Washington, D. C, 1939).

ing laboratories, and engineers are ready to raise commercial transmission voltages whenever they become economically feasible.

Limitations to electrical railroad transportation have developed only to be removed by new designs and higher voltages. Costs of production of electric power have been reduced by larger units, which were in turn brought about by new designs, as was the case, for instance, in the superseding of the reciprocating engine by the turbine engine. Many devices formerly hand-operated have been made automatic by devices of quicker and more discriminating action.

The extensive use of direct current by rectifying alternating current from power-transmission and distribution systems was first made possible by the development of the synchronous converter. But since 1937 a more efficient method of obtaining direct current from alternating current has resulted from the development of the Ignitron rectifier. This device differs from the conventional multianode tank-type rectifier in its method of excitation. By means of an igniter a cathode spot is formed in a mercury pool at the desired instant in the positive portion of the alternating current cycle. One of the largest single installations is a 3,000-kilowatt, 640-volt unit now delivering current to the New York Central Railroad's electric railway system in the heart of New York City.

The limitations upon transmission systems, imposed by lightning, have been reduced by constant improvement in lightning-protection apparatus. As a result of intensive lightning research carried out during the past 14 years, Westinghouse has developed the De-ion protective tube and the auto-valve lightning arrester, as well as a completely self-protected distribution transformer which is practically immune to lightning attack. The De-ion protector permits lightning surges to pass out of the power line, but the heat of the lightning on the tube's fiber plug forms insulating gases which prevent the line's normal current from following the lightning surge to ground. The lightning arrester performs a similar function by means of gaps and blocks of material which is resistant to relatively low voltages but offers no barrier to the flow of very high voltages such as are present in lightning strokes. During the summer of 1939 a multigap arrester, no larger than a quart-size fruit jar, discharged a lightning stroke which had a maximum crest of 21,000 amperes. Westinghouse engineers were able to measure this particular stroke by means of a newly developed lightning recorder known as the "Fulchronograph."

The capacity of certain apparatus is limited by allowable heating. Capacities have constantly undergone increase by improved methods of ventilation. Cooling by hydrogen gas, a better cooling medium than air, is moving limitations still further back.

Personnel Relations

The electrical manufacturing industry early in its existence appreciated the need of many technically trained men in its organizations. As far back as the late eighties graduates of technical schools were being given a course of special training in the manufacturing plants before they were

placed in permanent positions. The number of men taken in from the schools and the range of their training have been greatly increased as the industry has expanded, until several hundred graduates have been employed in a single year by one of the larger companies. The men are trained in various departments, and are finally placed in the departments in which they are best fitted to serve. Courses are also provided for apprentices, foremen, and other groups.

The industry has been a leader in those things which are generally designated as personnel relationships, in which both the employes and employer join in promoting activities which are of mutual benefit. Some of these are medical attention, sick and accident benefits, life insurance, and retirement annuities.

Engineering Societies and Trade Associations

In 1884, the electrical engineers of this country organized the American Institute of Electrical Engineers as a clearing house for their common problems and to promote standardization of engineering practices.

Later, in the early years of the twentieth century, various groups of manufacturers and engineers were formed, and many of these were combined in 1926 into the National Electrical Manufacturers Association.

The objects of this association, as stated in its constitution, are to promote and further the interests of manufacturers of electrical apparatus and supplies in manufacturing, engineering, safety, transportation, and other industrial problems; to promote standardization; to collect and disseminate information of value to its members or the public; to appear for its members before legislative committees, Government bureaus, and other bodies in regard to matters affecting the industry; to promote a spirit of coöperation among its members for the improved production, proper use, and increased distribution of electrical appliances; to increase the amount and improve the quality of electrical service to the public.

This association forms a common meeting ground for the various interests, where problems can be discussed and solutions reached. Mutual respect and confidence are engendered; more accurate knowledge of trade requirements is secured. It has brought about policing from within through self-restraint, rather than through law enforcement by the Government

This association also maintains contacts with other associations through joint committees.

Magnitude of the Industry

Speaking broadly of the entire industry, the *Electrical World*[5] says:

> The record is astonishing in magnitude and in rate of growth. Capital investment in the industry was $5,740,000,000 in 1910, $12,650,000,000 in 1920, and $23,590,000,000 in 1930. In 1910 the revenue or income figures were $1,025,000,000, in 1920 more than $3,370,000,000,

[5] *Electrical World* (January 3, 1931), Vol. XCVII. p. 10

> and in 1930 more than $6,240,000,000. In the first decade named the figures more than doubled, and in the second they almost doubled.
>
> Billions of dollars are beyond human comprehension and the growth of the electrical industry is measured better by simply observing the present degree of electrification in this country. In light, heat, power, transportation, communication, entertainment and other basic elements of life, the use of electricity and electrical equipment takes a tangible and indispensable form in everyday life and business Even though the markets are only touched, the evidence is available to show that the electrical industry is a necessary support for modern civilization. And it should not be forgotten that private initiative and enterprise have made these records possible. The structure was built by the men and women of the electrical industry.

It is a bold man who attempts to prophesy regarding the future, but there is every reason to believe that electrical manufacturing in the United States will continue to offer new developments and products that will advance the progress and welfare not of its citizens alone but of the whole world. The *Electrical World* states further:[6]

> Characteristic of the electric utility industry in its service to the nation is the fact that it continues the trend of decrease in cost of electricity to the user by establishing a new low of 4 05 cents per average kilowatt-hour for residential service. In 1929 the price was 55 per cent higher In the short space of ten years the average residential customer's purchase of energy has increased 80 per cent, but his bill has increased only 16.4 per cent. The bill has increased only one-fifth as fast as usage has increased.

Possible Future Developments

Since we know so little about nature's basic underlying principles, it is incredible that anyone should think of our knowledge of natural laws as anything but exceedingly small when compared with the vast amount listed in the unknown column. This alone should be encouraging for the future, for if we can accomplish all that we have with such a poor understanding, it is reasonable to expect vastly better results as we obtain more basic knowledge.

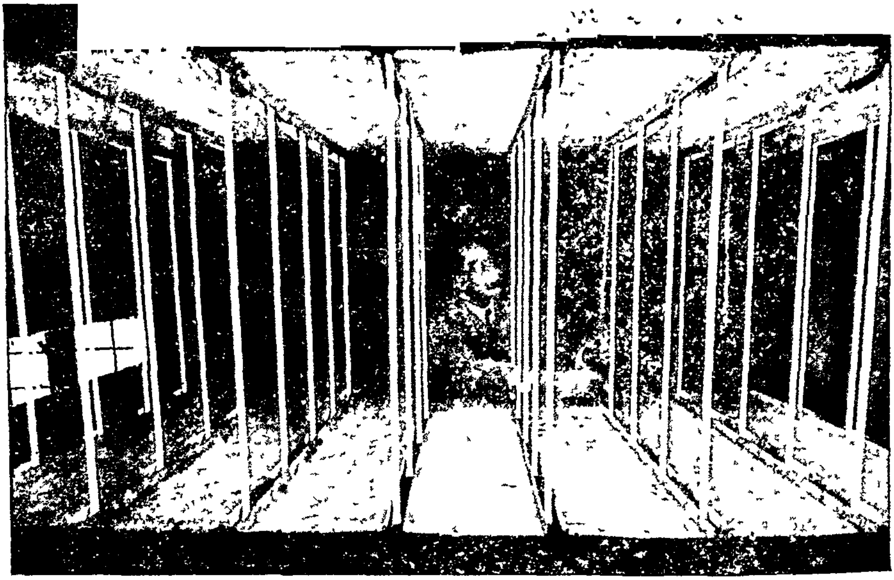
While our human limitations may prevent us from seeing very far into the future, present developments give us some idea of future trends and in what fields expansions are likely to occur.

In the processing industries, electricity will probably assume an increasing important role in the way of metering, regulating, and controlling numerous phases of new as well as existing processes. Recent improvements in electric furnaces and their controls, including the control of the atmosphere inside of the furnace as well, indicate various possibilities in this field. For instance, heat treatment of steel sheets for automobiles by continuous processes in less than 15 minutes has been accomplished. In the presence of highly purified atmospheres, various steels and alloys can now be bright-annealed. In controlled-atmosphere furnaces, dies can be heat-treated without oxidization or carburization, thus eliminating subsequent grinding.

[6] *Ibid.* (January 13, 1940), Vol 113, No 2, p. 84.

In the broad field of air conditioning, electricity will play an important part, not only in applications requiring power but in the processing and treatment of the air itself. Electrical means are now available for cleaning and sterilizing air. These new aids in air conditioning, coupled with the available services of heating, cooling, and humidity control, make it possible to improve man's living conditions so profoundly that he may live in a clean spring or fall atmosphere all the year around in any locality.

Lightningproof electrical systems were but the dreams of engineers a few years ago. They are still not a reality, but the day is coming when



Courtesy, Westinghouse Electric and Manufacturing Company

Fig. 4. Death trap for bacteria in an air-conditioning system in this battery of 40 Westinghouse Sterilamps in a duct serving the auditorium at the Westinghouse Lamp Division, Bloomfield, N. J. Dr. Rudolph Nagy, research engineer, is shown fitting a lamp into its special sockets in the duct Efficient sources of bactericidal ultraviolet rays, the Sterilamps shown here were found to kill more than 99 per cent of all bacteria that passed through the duct.

they will be. Much has been done in this direction; more is yet to be done. We now have reason to believe that in the not too distant future lightning, once the great disturber of electrical systems, will be eliminated as a hazard to power continuity.

Vast new vistas are being opened by high-frequency electric energy. High frequencies, which broadly include everything beyond 60 cycles, are already being used for numerous tasks of melting, heat-treating, and drying. Packaged raw materials are being dried without opening the containers; bearing surfaces of finished engine crankshafts are being given additional hardness by localized heating induced by high-frequency currents. With the rapid developments in high-frequency generators,

both of the rotating and electron-tube types, it is not inconceivable that all gasoline and Diesel engines, machine tools, and other machines will be treated by high-frequency when assembled or partially assembled to harden the wearing surfaces.

The great field of electronics, which is now best known in radio, television, and communication, can be expected to find a greater number of future applications in the electrical industry, particularly in those fields having to do with automatic machine operations, inspection of materials, and safety methods. Recent progress in the development of larger and more reliable metal tank tubes indicates that electronics may also be expected to play an increasingly important part in electric-power distribution, both in transformations and control.

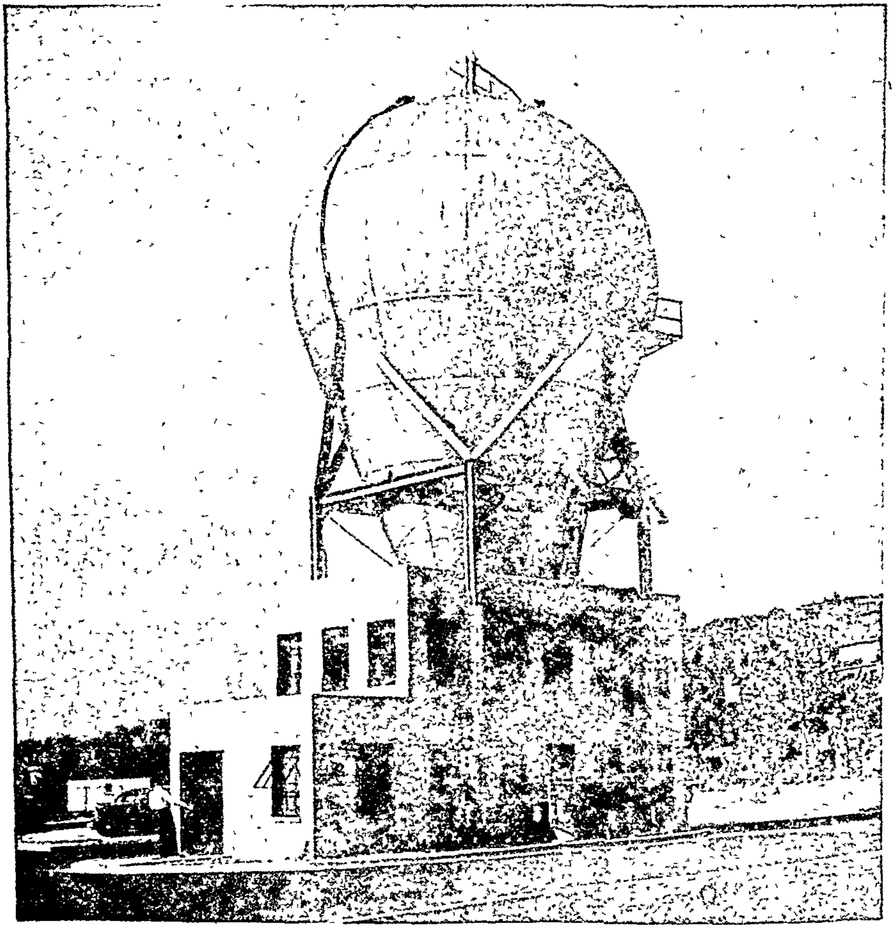
When we consider that the power consumption in many small homes today is from three to ten times the national average—owing to the increasing acceptance of electric ranges, water heaters, forced air circulation, high lighting levels, and other conveniences—we can expect domestic power consumption to double in a reasonable time. This indicates the need for an improved low-voltage distribution system as well as rewiring of homes.

Agriculture is another field that has scarcely been touched by the electrical industry. In addition to the usual applications of power and light, there appear to be many possibilities of applying treatments and radiations for the stimulation of plant growth and control of insects that now infest grains, plants, and seeds.

Present researches in nuclear physics in many institutions may result in obtaining information that will be just as extensive in its influence on the developments in the electrical industry as was the discovery of the electron. The production of radioactive substances, through the disintegration of the atom, may provide a very useful tool. Naturally, one thinks of using these radiations instead of the X ray for radiography or for radium in the treatment of disease. While they no doubt will be used to some extent for such purposes, the possibility of using these radiations as a means of studying certain atomic reactions and structures may be even more useful. For instance, by the use of electrical detection methods, it appears feasible to follow the migration of radioactive atoms through a metal during heat-treating processes. Similarly, it is possible to trace the movement of radioactive substances through a plant or the human body and thus learn more about how and where these substances are assimilated. In contrast to radium, most of these artificial radioactive substances have such a short life that no permanent harm is done to the human system.

The present methods of generating electric power are so well established that we are inclined to accept them as permanent. Gradual improvements in present methods have reduced the amount of coal used per kilowatt-hour to approximately one fourth that required 20 years ago. While this improvement is indicative of real progress in steam-power generation, it is still small when compared with the theoretically possible energy that could be gotten from a highly efficient method of energy conversion. Fuel efficiency is, however, good enough that the cost of fuel

represents only a small part of the cost of generating electricity. It is today cheaper to generate power from steam locally than to build expensive hydroelectric plants for transmission lines. In fact, it has been calculated that, were a feasible perpetual motion machine to be developed, it would not be economical to use it if the power plant in which it were installed cost 50 per cent more than a modern steam power plant.



Courtesy, Westinghouse Electric and Manufacturing Company

Fig. 5. New key to matter's secrets. Man's newest duplicator of nature's radium bombardments, this 90-ton pear-shaped "cannon" at the Westinghouse Research Laboratories (East Pittsburgh, Pa.) already mobilizes 4,000,000 volts to shoot subatomic particles at tiny targets. Particles hurtle through its 40-foot vacuum tube at speeds approaching 100,000,000 miles an hour.

Although these and many other prospective developments that might be mentioned are indefinite and difficult to evaluate, we can look forward with the expectation that the electrical industry will continue to grow under the stimulation and impetus of new scientific discoveries and advances.

28

The Power Industry

Early History of Power

Man power. For a great many years after man appeared upon the earth, all of his labors were performed by his own muscle. He brought mechanical devices to his aid early, however. Perhaps the first conception of power transmission was gained by prehistoric man from watching rounded stones roll downhill. This observation was perhaps made use of in devising crude stone wheels, which were fastened to the end of a sled for transporting materials.

It is generally conceded that the great pyramids of Egypt were constructed entirely by manual labor. But while the Egyptians obviously had already developed some devices to increase the effectiveness of man's muscle and lessen his burdens, no one has yet been able to learn exactly how these huge stones were raised into place.

In later years, within historic times, mills were developed to supply rotating motion from man power. These mills, operated by treadles, are still in extensive use in China, Africa, and some of the remote corners of Russia and Siberia. Modern civilization, however, has to a great extent eliminated the use of man as the sole physical means of generating power. We now employ the worker in guiding parts through machines and in directing their operation, but the power of operation is supplied by some outside source.

Animal power. Man, early in his history, domesticated animals and employed those of superior strength to assist him with his burdens. The elephant, for example, is of great economic importance in the tropics. We are familiar also with the extensive use in various parts of the world of donkeys, oxen, horses, and mules.

The horse, a native of Arabia, has been, perhaps more than any other animal, man's faithful servant. Until the last century, the horse supplied by far the major part of the power utilized. So dependent, in fact, was man upon the horse that, when other sources of power began to be devised, their effectiveness was measured in terms of what a horse could do on the same job. Thus the unit of horsepower, now in universal use, came into being, although it is interesting to observe that the value of 1 horsepower,[1]

[1] Horsepower is commonly abbreviated "hp"

as ultimately standardized, is considerably less than the effort which can be exerted by the average horse.

In 1927, working animals supplied 2.5 per cent of the power used in the United States. Although mechanical and electrical power is being adapted more and more to the tasks found on the American farm, animal power is still much in use there. In 1850, oxen accounted for approximately 30 per cent of all power developed on the farm, although today oxen have practically disappeared as beasts of burden. Nevertheless, in 1924, mules supplied 9 per cent and horses 35 per cent of the power used on the American farm, the total animal power being equivalent to 22,000,000 horsepower.

Wind power. The wind was first used for propelling ships. It was later learned that, by proper construction, a fan could be developed which would cause the wind to turn machinery, and contrivances like the windmill came into use. But because of its unreliability and, for mills of large size, feebleness, wind power never became standard. In 1927, the wind supplied only one tenth of 1 per cent of the power used in the United States, and most of this was generated for the farm.

Water power. That energy was available in a stream of falling water was learned early in history. This energy was not taken advantage of, however, until the eighteenth century, when water wheels were developed.

The early water wheel. The first water wheel was a simple, flat paddle, similar to the wheel of a Mississippi River steamboat. This wheel was placed in a flowing stream, where the velocity of the water caused it to turn. It was later discovered that more energy was available in a swift stream than in a sluggish stream, and that maximum energy was obtained if the paddle wheel was placed in a waterfall.

Improvements were made in the flat water wheel when it was found that more power could be developed if the weight of the water as well as its velocity was taken advantage of. For this reason, the flat paddles were replaced by curved buckets. Thus the buckets, filled at the top and discharged at the bottom, caused the wheel to turn by the weight of the water. This type of wheel was called the "overshot wheel." Two other types of wheels developed were the "breast wheel" and "undershot wheel." The breast wheel received the water on the upstream side and passed it underneath; the undershot wheel was merely a more efficient design of the original flat-paddle wheel.

Hydraulic turbines. Early mills were located along streams or at waterfalls, so that the energy from these natural sources could be used.

The wastefulness of the water wheel and its general poor adaptability to large power outputs led to the development, in 1804, of the first hydraulic turbines. Turbines have now almost entirely replaced the old water wheel.

A hydraulic turbine is distinguished from a water wheel in that it is entirely enclosed. Water is taken from above the fall or dam into a conduit or head race, as shown in Figure 1. After passing through the turbine, the water is discharged into the tail race through a closed draft

tube or—depending upon the design of the turbine—through an open flume.

Three general types of turbines are in use today: the reaction, or Francis, turbine; the impulse, or Pelton, turbine; and the propeller-type turbine. In the reaction turbine, the weight of the water, or static head, is only partially transformed into velocity, thus leaving pressure between the case, or stationary part of the turbine, and the runner, or moving portion. The reaction pressure thus developed causes the turbine to accelerate.

The impulse turbine derives its energy entirely from the velocity of the water, for the static head is completely transformed into velocity. As the name indicates, the jet of water issuing from the nozzle develops an impulse on each bucket of the wheel.

Fig. 1. Airplane view of Vernon Dam, Connecticut River.

The propeller-type turbine is really a modification of the reaction, or Francis, runner. By flattening out the blades and omitting the shroud around them, the propeller runner has the appearance of the propeller of an ocean steamship. A recent development is the adjustable blade runner, whereby the pitch or slope of the blades can be adjusted either manually or automatically, according to the load being carried. These blades are pivoted in the center, where they fasten into the shaft, and by a turning to the proper angle for the load being carried, the efficiency of the turbine can be maintained at the maximum for practically the entire range from no load to full load.

In 1869, water power accounted for 50 per cent (1,150,000 h.p.) of the power used in the industries of America. The water wheels at that time were all mechanically connected to the machinery to be driven, either through belts or through line shafting. Water power was first used to

drive an electric generator in 1882, at Appleton, Wisconsin. This initial plant could generate only about 40 h.p

Inherently, the old water wheel was a horizontal machine. The modern hydraulic turbine, on the other hand, works best as a vertical machine For a number of years after the adoption of vertical turbines, electric generators were still of the horizontal type, being belted to the turbine or geared through large bevel gears. Later, satisfactory vertical generators were developed, so that modern machines have the generator on the same shaft above the turbine. (See Figure 2.) Owing to the slow speed of hydraulic equipment as compared with other classes of prime movers, hydroelectric generators are large in diameter for their capacity.

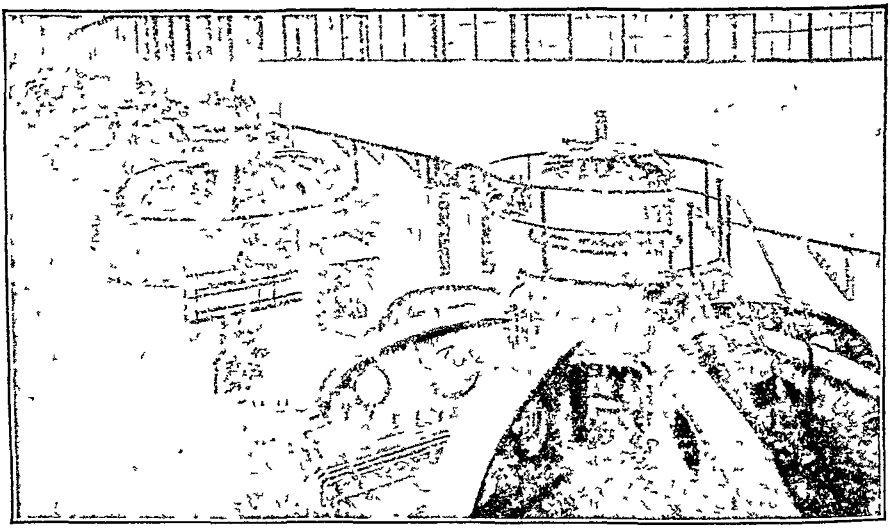


Fig. 2 12,550-KV-A , water-wheel-driven A-C generators with surface air coolers, automatic control, and circuit breakers

The principal features of Boulder Dam and its powerhouse, at present the largest electrical plant in the world, are shown in Figure 4. A diagram showing the utilization of hydro power as contrasted with other kinds of power in the United States today may be found on page 603.

Steam power. Ordinarily credit for the development of steam power is given to James Watt, and the general public thinks Watt discovered the force of steam as a small boy, when watching his mother's boiling tea kettle raise the lid. As a matter of fact, steam engines were in use long before Watt's time. However, great credit is due this eminent engineer for important improvements on the steam engine which brought it within the realm of practicability.

Heron's steam turbine. The first recorded use of steam for motive power was made by Heron, of Alexandria, in his elementary turbine, built in 150 B C. This was purely an experimental proposition, for sufficient power to perform any work could not be developed with the small device.

Oddly enough, the principles on which this early turbine was based, although they lay unused for centuries, are employed in certain classes of steam turbines used today. Heron's turbine consisted of a hollow sphere, or boiler, supported at either side by bearings. Two pipes, bent at right angles, opened to the atmosphere from the boiler. Upon heating the water in the boiler, the steam generated would pass through the two pipes, and its impingement on the atmosphere caused the rotary motion of the first steam reaction turbine.

First practical steam engines. Perhaps the credit for the first useful steam engine should be given to Edward Somerset, second Marquis of Worcester, who, in 1663, described in London a reciprocating piston operating like a pump. Somerset's descriptions were, however, rather vague

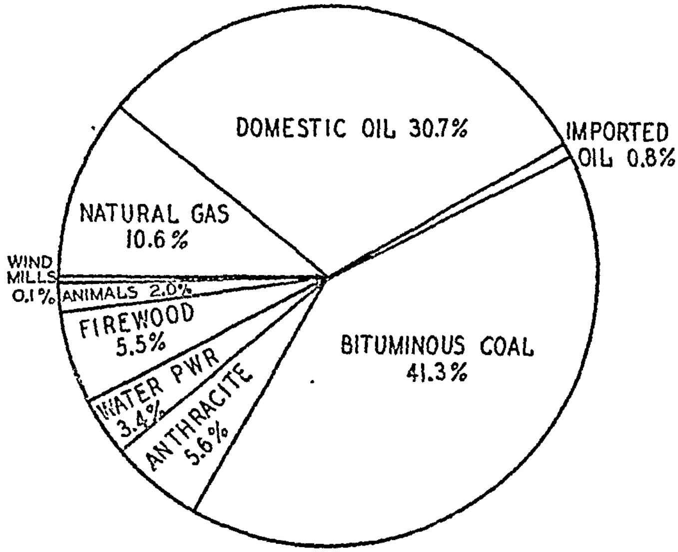


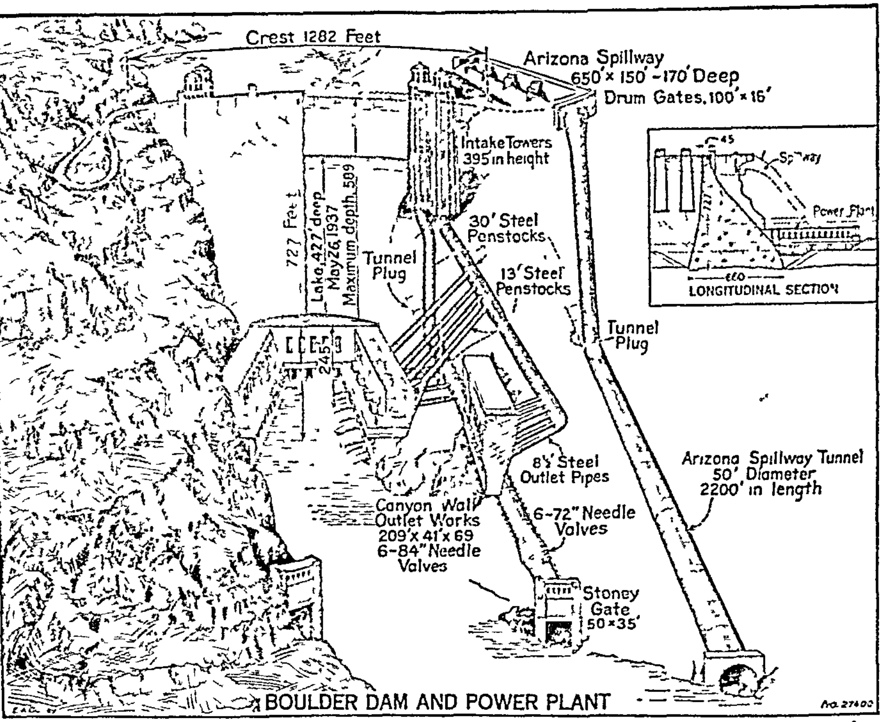
FIG 3. Sources of the energy supply of the United States in 1939, including that derived from work animals, windmills, and firewood (Mineral fuels as shown in the *Minerals Year Book*, 1940, page 789, with water power at prevailing fuel equivalent of electric power plants)

and incomplete. The first commercially successful steam engine was demonstrated before the Royal Society of England by Thomas Savery, in 1699. Sir Isaac Newton, it is interesting to note, was president of the society at the time.

Mention should be made here also of Dr. Denys Papin, who, in 1690, developed the present boiler safety valve and first conceived the idea of bringing the exhaust pressure down to a vacuum by cooling the engine cylinder. Papin's ideas and other improvements were put into use by Thomas Newcomen, and until Watt's time, the Newcomen engine was used extensively.

All of these early engines caused a piston to operate in one direction,

the return stroke being obtained by gravity or by the application of steam to the opposite side of the piston. In both operations, valves turning the steam off and on had to be manipulated manually. Everyone is familiar with the story of the small boy, Humphrey Potter, whose duty



From "Description of Boulder Dam," published by the U. S. Bureau of Reclamation

Fig. 4 Boulder Dam and power plant. This drawing shows how Boulder Dam works The Nevada wall of Black Canyon of the Colorado River is shown solid, but the Arizona wall has been cut away to reveal the intake towers, the spillway, the penstock pipes, and outlet works. Inside the Nevada wall of the canyon a similar set of diversion works has been placed Principal dimensions are shown.

The powerhouse, here shown dwarfed in the bottom of the canyon, is a city block long and as high as a 20-story building. In it ultimately will be installed 15 generators of 82,500 kilovolt-ampere capacity and 2 of 40,000 kilovolt-ampere capacity. An idea of the comparative capacities of the 15 big generators may be obtained from the fact that the small ones are about as large as any others in the world.

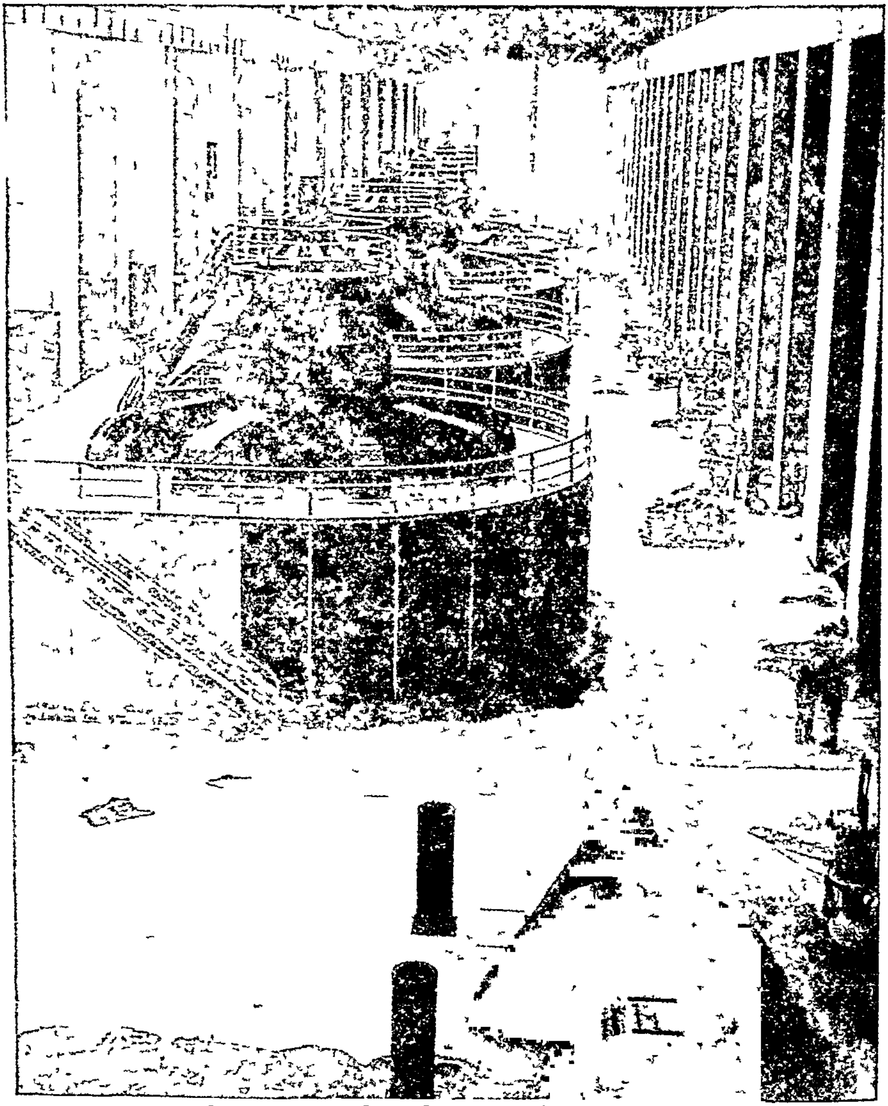
The tunnels originally used to divert the Colorado River around the dam site during the period when Boulder Dam was under construction, now are used in the penstock and outlet system for the greater part of their lengths They have been plugged upstream from the points at which the continuously useful outlets enter them, as can be seen in the drawing.

it was to open and shut the valves of an engine operating in a mine. In 1713, Potter, who tired of his job and wanted to go fishing, rigged up a set of cords and attached them to the beam of the engine, causing the valves to operate automatically. Thus the first valve gear was developed.

Courtesy, United States Department of the Interior, Bureau of Reclamation

Fig. 5 General view of Boulder Dam

Inventions of James Watt Then, in 1763, James Watt, an instrument maker of Glasgow, was impressed while repairing a Newcomen engine with the great waste of steam caused by the alternate cooling and heating of the engine cylinder This observation led to the development of his own engine, in which he attempted to keep the cylinder always at the same temperature as the incoming steam, first by insulating it with a wood covering and later by jacketing it with live steam. Watt also caused the condensation of the exhaust steam to take place in a vessel



Courtesy, United States Department of the Interior, Bureau of Reclamation

Fig 6 Initial installation at Boulder Dam.

separate from the engine cylinder and, by the application of cold water outside or a jet within, took advantage of the pressures below atmospheric pressure. Thus was developed our modern condenser.

Watt's early efforts are typical of a poor inventor struggling for recognition with insufficient resources. It was not until he became associated with a wealthy manufacturer, Matthew Boulton of Birmingham, that he met with the success upon which his present fame is based.

Modern steam engines. Later developments of the steam engine brought about the compound engine, wherein the steam passes through two or more cylinders before it finally exhausts to the atmosphere or to the condenser. Thus, by the limiting of the temperature changes in any one cylinder, greater economies are made possible.

The most modern development in steam engine design is the uniflow engine. As the name implies, the steam always moves in the same direction—that is, the exhaust valves are at the opposite end of the cylinder from the inlet valves. This gives the minimum of heating and cooling in the cylinder, and affords the maximum economy to be expected from the steam engine.

Steam turbines. In the latter part of the nineteenth century, engineers began to develop a substitute for the steam engine in an effort to produce greater economies and larger sizes. The steam engine had been built in sizes around 7,500 kw.[2] Such a machine was so massive as to become almost unwieldy. Heron's original idea was developed, and the first commercially practical steam turbine was made by Parsons in England.

Steam turbines, like water turbines, are of two types—the impulse and the reaction—named according to the way they utilize the energy in the steam. Most modern turbines have both impulse and reaction stages. In the turbine, the full expansive effect of the steam is taken advantage of, and inasmuch as there is a steady flow of steam always in the same direction, there is no alternate heating and cooling. The absence of this objectionable factor is conducive to great economies.

Inherently, the steam turbine is adaptable to high rotative speeds, smaller sizes operating at 3,600 r.p.m.,[3] as contrasted with the old Corliss engine speed of 90 r.p.m. This factor enables the turbine to be built in very large units, requiring the minimum of floor space. Capacities as high as 220,000 kw. have been installed in a single unit

In 1875, steam engines supplied 60 per cent of the power used in industry in America. The peak of usefulness of the steam engine was reached in 1900, when this type of prime mover supplied 82 per cent of the power for industrial plants. From this time on, the steam engine gradually gave way to the more modern steam turbine, until, in 1925, the engine was supplying only 58 per cent and turbines 28 per cent of the industrial power. In the central station, which will be taken up later, the steam engine has been almost entirely replaced by steam turbines.

[2] Kilowatt is commonly abbreviated "kw."

[3] Revolutions per minute is commonly abbreviated "r.p m."

For small loads, however, the economies of the turbine are not so marked, and the engine is still extensively used in the industrial plant.

The progressive improvement in the use of steam as a prime mover, as indicated by the amount of coal necessary to produce 1 horsepower-hour of mechanical energy, is shown in Figure 7.

Internal-combustion power. In 1678, Hautefeuille discovered gunpowder. The force which could be developed by an explosion of this material was a marvel of the age. Many years afterward this explosive

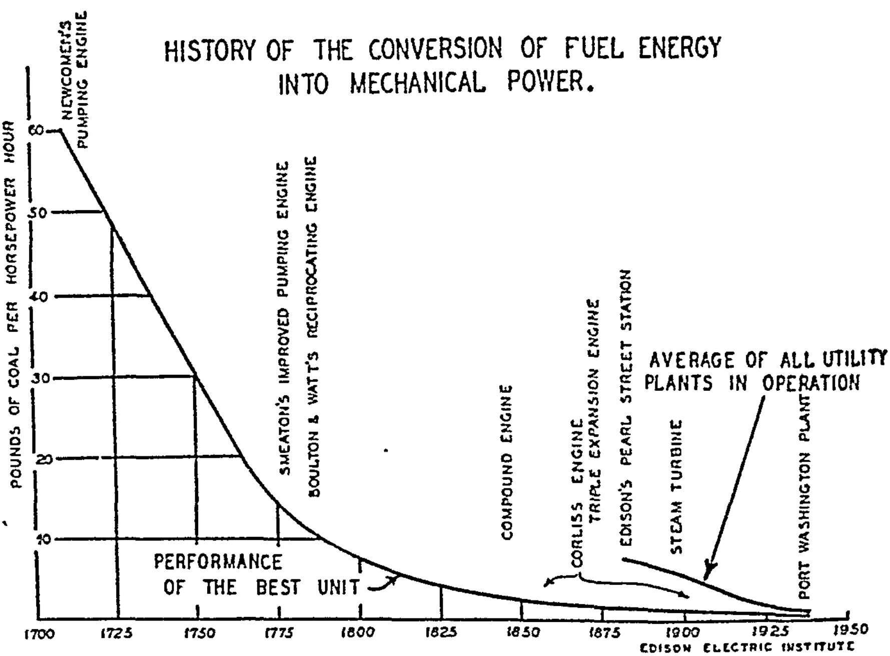


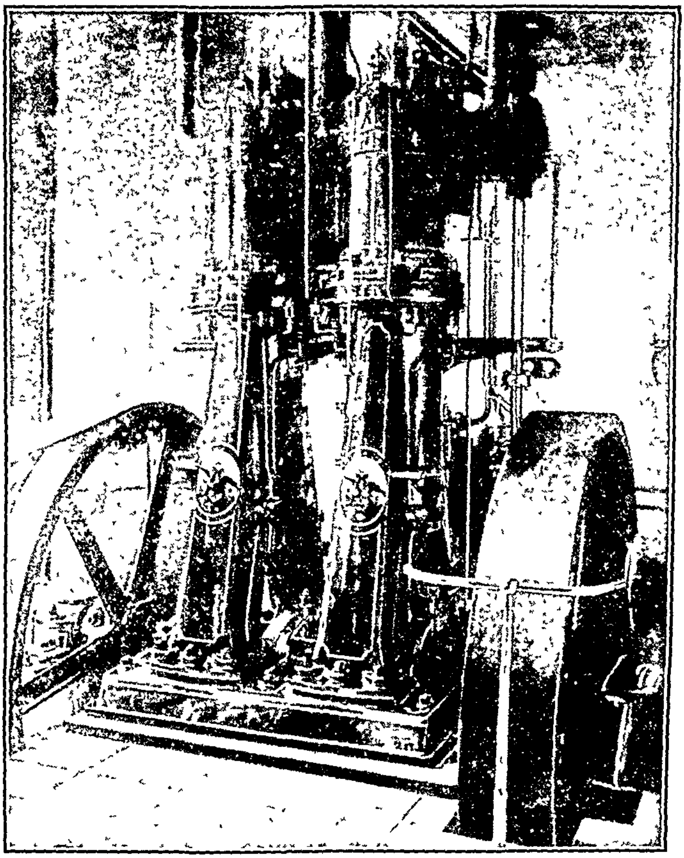
Fig. 7. This chart, based upon that of Professor R. H. Thurston of Cornell University in the *Transactions of the American Society of Engineers*, 1900, shows the amount of coal required to produce a horsepower-hour by various devices since 1712. Though not shown, almost as much credit for increased fuel economy is due to boilers as it is to engines

force was put to work in driving a piston back and forth in an engine.

Otto's engine. In 1864, Dr. Nicholas Otto, of Germany, invented the first internal-combustion engine. Dr. Otto's sputtering engine was demonstrated at the World's Fair in Paris, in 1876, and this new source of power caused much discussion. Vaporized oil fuel was intermittently exposed to the surface of a hot tube, and the explosive effect delivered power to the piston. Modern engines use an electric spark to ignite the fuel, and the automobile engine as now developed is essentially the same as the machine invented by Otto. Indeed, the cycle under which the gasoline engine operates still bears the name of Otto. Like most inventors, Dr. Otto struggled throughout his life for recognition and died

when the world was just beginning to recognize the importance of his invention.

The gasoline engine is admirably adapted to the use to which it has chiefly been put—that is, to drive motor vehicles. Its ease of control, light weight, economies in small sizes, and the fact that it can be started upon a moment's notice are the most important advantages. However,



Courtesy, Busch-Sulzer Bros.-Diesel Engine Company

Fig. 8 First Diesel engine built in United States and first Diesel to be put in commercial service in the world. Completed by Adolphus Busch at St. Louis, Mo., in September, 1898.

it is not adaptable to large units, and for this reason more than for any other, the gasoline engine has never been used to generate power, except when small sets are used for emergency service.

Diesel engine. In 1895, Dr. Rudolph Diesel, another German, developed the internal-combustion engine which bears his name. This engine is much heavier than the Otto engine. Air is introduced into the cylinder and compressed to a very high pressure. The exertion of this pressure raises the temperature of the air to a high degree, and at this

point oil fuel is injected into the cylinder, where the high temperature of the air ignites it.

The Diesel cycle is more efficient than the Otto cycle. In fact, the Diesel engine is the most efficient prime mover that has yet been developed. It has its limitations, however, the paramount disadvantage being its poor adaptability to the giant sizes possible with steam units. About 4,000 h p. is the largest Diesel that has been built. This is the limit of practicable size, since larger units involve piston diameters too great for efficient cooling. As a rule, a Diesel plant can generate energy cheaper than a steam plant in capacities under 10,000 kw. Above this capacity, the steam plant has the advantage.

In 1889, there was derived only 8,930 h.p. from all internal-combustion engines installed in manufacturing plants in the United States, but by 1927 this capacity had grown to 1,233,853 h.p. In 1899, internal-combustion engines constituted 1.3 per cent of the prime movers in American industry; electric motors operating on purchased power constituted only 1.8 per cent. In 1929, according to the last tabulation of factory power by the United States Census of Manufactures, internal-combustion engines constituted 3 per cent of the total, while electric motors operating on purchased power supplied 53 per cent. Both of these increases were at the expense of steam, the installation of which in factories decreased from 82 per cent in 1899 to 40.5 per cent in 1929, and of water power, which decreased from 14.5 per cent of the total in 1899 to 3.6 per cent in 1929.

Electrical power. The first engines were used entirely for pumping water. Early water wheels were attached directly to the mill to be driven. For a long time, all machines were fastened directly in this manner. But the complexity of industry and the inconvenience of always locating the machinery exactly at the source of the power required that some system of power transmission be developed. Shafting, belts, pulleys, and gears were devised. But these mechanical methods of power transmission have their limitations, their efficiency depending on the distance (from the source of power to the place where the power is used) at which they are operated. Electricity is a means of power transmission and not a separate source of power, such as coal, oil, or waterfalls. Consequently, as a power-transmission medium, electricity is classified with compressed air, steam, hydraulic power, and the mechanical devices mentioned above.

Electricity is by far the most efficient means of transmitting power, its adaptability to transmission over great distances and the ease with which it can be controlled in performing almost any task having led to its amazingly wide development.

Early discoveries in electricity. Benjamin Franklin is credited by the average person with "discovering" electricity. Without attempting to deprecate the value of Franklin's discoveries, it should be said that the presence of electrical energy was known centuries before his time. As early as 600 B.C., Thales, a Greek philosopher, observed the attraction and repulsion of lightweight objects when put near amber which had

previously been rubbed with fur. Also, in 100 A.D., Plutarch recorded the presence of certain magnetic stones.

After the sum of man's knowledge on this subject had lain dormant for 2,000 years, the first important experiments in electricity were conducted by Dr. William Gilbert, a physician to Queen Elizabeth, in 1600. Gilbert discovered some of the fundamental laws of magnetism, and his work was of such importance that he has been called "the father of electricity."

The next hundred years were spent in building various types of "static machines," consisting of glass discs that were revolved against stationary pieces of silk or fur. The static charges thus set up had little relation to the constant flow of electrical energy as we know it today, but they did assist in some important discoveries. It was found that the charges could be conducted along certain materials and that other materials acted as insulators. Then, in 1745, Bishop von Kleist discovered the Leyden jar, by means of which charges of electricity could be stored.

Perhaps the most important electrical discovery ever made was that of the voltaic pile by Alessandro Volta, in 1796. This device consisted of a series of discs of silver, zinc, and cloth wet with salt water, and constituted the first use ever made of chemical electricity. Our modern dry battery is not unlike the voltaic pile. Very shortly thereafter, in 1809, Sir Humphrey Davy invented the arc light. He showed that, by placing together two sticks of carbon connected to a voltaic pile, and then drawing them apart, a very brilliant light was produced.

The relation between electricity and magnetism was discovered in 1819 by Hans Christian Oersted, who, by accident, noticed that a wire carrying a current in one direction deflected a compass needle one way and that a current flowing in the opposite direction deflected it the other way. After this came the discoveries of André-Marie Ampère, who found that a strong magnet was produced by passing an electric current through a coil of wire. This discovery brought about the development of the solenoid, which is in use today.

Even the layman is familiar with Ohm's law. In 1827, Dr. G. S. Ohm, of Berlin, set down in mathematical computations this important principle of the electric circuit. The well-known developments of Samuel F. B. Morse and Alexander Graham Bell in adapting electricity to communication followed.

The first dynamo. Previous to the discovery by Michael Faraday, all electricity was produced chemically. In 1831, Faraday demonstrated the first dynamo, by means of which electricity could be generated by mechanical power. This discovery led to the rapid adoption of the arc light as a means of illumination. Then, in 1875, at Cornell University, Professor William A. Anthony and George S. Moler built and put into use the first practical dynamo constructed in the Western Hemisphere. This dynamo furnished the electricity to light the campus of Cornell University, while New York and Paris still used the flickering gas jet.

The realization that the arc light was too large and inefficient for interior illumination led to the famous invention, on October 21, 1879, of

the first practical carbon-filament lamp by Thomas Alva Edison. The discovery that a dynamo supplied with electrical energy would run as a motor led to the development of the electric motor.

All these earlier devices used direct current, and it was not until George Westinghouse spent untiring efforts in trying to establish the use of alternating current that its many advantages became apparent. Westinghouse's first installation was the lighting of the World's Columbia Exposition in Chicago, in 1893.

Development of the central station. As soon as a means of transmitting energy was developed, the inherent advantages of generating energy at one central point were readily realized. The first central station was put in operation by Thomas Edison on September 4, 1882, at Pearl Street, in New York City. The rating of the first station was 2,000 h.p., with 5,500 lamps in circuit. In a short time, 508 customers' houses had been wired and there were 12,732 lamps in circuit. Then, about a month afterward (October 15, 1882), the first hydroelectric station was placed in operation at Appleton, Wisconsin. The success of these early stations led to an enormous expansion of the service in all parts of the country.

These early steam stations had all been operated by steam engines. But in 1901, a 1,500-kw. steam-turbine unit was installed at Hartford, Connecticut. Shortly afterward, in 1903, a 5,000-kw. steam-turbine unit was installed in the Fisk Street station at Chicago, the first all-turbine station in the world.

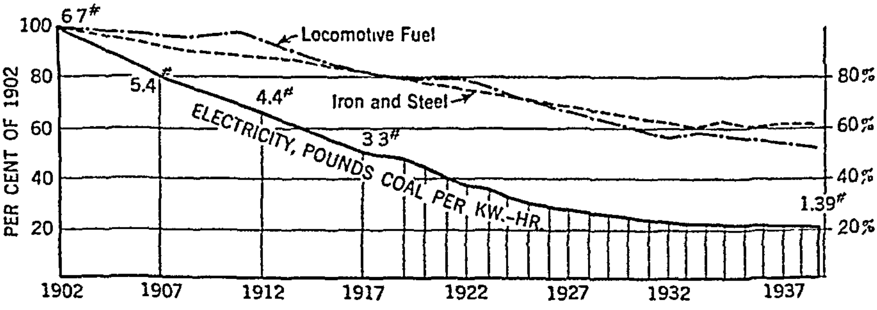


Fig. 9 Increasing efficiency in the use of fuel, showing the relative decrease in the amount of coal used, per unit of output, by the railroads, the iron and steel industry, and the electric light and power plants of the United States.

Constant increase in efficiencies of generating stations. The advent of the steam turbine has done much toward the conservation of the country's fuel resources. About 2½ pounds of coal per kilowatt-hour represents the best recorded performance of a reciprocating-engine plant. This economy was accomplished by the Manhattan station of the Interborough Rapid Transit Company of New York with the largest reciprocating units ever built. Today, power stations operating giant turbines are generating 1 kilowatt-hour with .86 pounds of coal. Constant improvement in turbine and boiler design is responsible for these economies and for the resulting ever-decreasing cost of power. New devices are being

developed for recovering more and more of the heat in the coal fired under the boiler.

As contrasted with the figures given above, representing the best recorded efficiencies, the average for all the power plants in the United States in 1902 was 6.7 pounds of coal per kilowatt-hour (see Figure 9). In 1939, the average for the entire country had dropped to 1.4 pounds of coal per kilowatt-hour. A proper conception of the importance of these growing efficiencies cannot be gained without making a few comparisons. Even when considering just the 20-year period from 1919 to 1939, only 50 per cent more fuel was used in 1939 than in 1919, and yet considerably over three times the energy was generated. In other words, 775,000,000 tons of coal (or its equivalent in other fuels) have been saved since 1919 as a result of increased efficiencies.

Interconnected systems. Yet, all of this increased efficiency is not due to larger units or improved facilities. It was found, not only that a central generating station could produce energy much more economically than a number of small private plants, but also that, when a number of central stations were connected together, a load factor better than that of the worst station always resulted. When power is available from the most economic plant on the system, this plant is operated to furnish power for the entire system, the other plants being maintained as standbys for extra-demand periods. Consequently, a complicated interconnected system has been established throughout the eastern half of the United States. Large power pools have been formed whereby power is dispatched from a central point and always obtained from the most economical point.

Hydro Versus Steam Power

Most people have an improper conception of the importance of hydroelectric power, as well as of the economics connected with this source of energy. It is the general belief that water power costs nothing and that, for this reason every available water site should be developed at once. As a matter of fact, hydro energy[4] sometimes costs a great deal more than steam energy, in which event it is naturally more profitable to build a steam plant.

Few persons realize the enormous energy contained in 1 pound of coal. It is four or five times that of 1 pound of T.N.T., and 1 ton of water must fall 1 mile to develop its energy equivalent.[5] Even when it is considered that only one third of the energy in the coal eventually is transformed into electrical energy, it still holds true that 1 ton of water must fall ⅓ of a mile to produce in electrical form the energy that can be generated

[4] Energy generated by water power.

[5] One British thermal unit (or the energy required to raise the temperature of 1 pound of water 1 degree F) is equivalent to 778½ foot-pounds (or the energy required to raise 1 pound 778½ feet). A ton of good coal will contain 13.500 Btu's, or 10,510,000 foot-pounds; this is equivalent to 2,000 pounds of water falling 5,255 feet

from 1 pound of coal. As a comparison, it is interesting to note that the entire flow of Niagara Falls is equivalent to an imaginary stream of coal flowing at a rate only slightly faster than a walk through a pipe line only 18 inches in *diameter*.

Coal resources. It is true that every kilowatt-hour generated by water power conserves at least 1 pound of one of our most valuable resources, namely, coal. But an improper conception exists in the minds of the general public concerning the seriousness of depleting our coal reserves. Figures published by the Bureau of Mines indicate that we have taken little from the supply of coal. For instance, in Pennsylvania, where the greatest depletion has occurred, it was estimated that there were originally 133,148,000,000 tons of coal under the ground down to the depth of mining practicability, of which, to date, only 7,530,000,000 tons have been removed. Similar statistics for other prominent coal-mining states are as follows:

State	*Amount Originally Estimated as Available*	*Amount Mined Through 1937*
West Virginia	152,514,000,000	3,250,331,000
Kentucky	123,327,000,000	1,200,969,000
Illinois	201,400,000,000	2,405,891,000
Indiana	53,051,000,000	721,090,000

Potential water-power resources. At the end of 1869, there had been installed in the United States hydro capacity for 1,150,000 h.p. This figure grew, until on January 1, 1931, there was in operation hydro-capacity to the equivalent of 14,885,000 h.p. According to the United States Geological Survey, the potential water-power resources of our country are 38,110,000 h.p. available 90 per cent of the time, and 59,166,000 h.p. available 50 per cent of the time. The figures for installed capacity and potential water power are not exactly comparable, inasmuch as the installed water turbines at any particular site are usually several times the firm power available at that site. This is due to the desire to obtain peak capacities out of the plants during times of abundant water supply.

It is estimated that about one fifth of the total potential water-power resources of the United States is already developed. In 1920, 16,150,000,000 kilowatt-hours were generated by hydroelectric-power plants, while in 1939, 44,025,000,000 kilowatt-hours were so generated. Contrary to general belief, this represents only about 34 per cent of the total power generated in the United States, and this ratio has remained fairly constant. That is, hydroelectric plants have been developed at just about the same rate as the constantly increasing demand for power.

Many limitations accompany the advantages of water power. Because they utilize the flow of water from the Great Lakes, the water-power plants at Sault Ste. Marie, Michigan, and at Niagara Falls are unusual in that they provide practically a constant flow of power which is nearly uniform throughout the year. With these and a few other exceptions, however, the flow of water in our streams is subject to wide

seasonal variations. The streams are usually very low during the summer. So it can easily be seen that water is not always available when power is needed. For this reason, there are few instances where a system can depend upon water power alone. In most cases, a water-power plant must be supplemented by a steam plant. This necessary duplication of equipment serves to increase the cost of hydro energy.

Fixed charges. Many who are unfamiliar with the power business are inclined to neglect fixed charges when figuring the cost of power. But fixed charges are just as real as operating or maintenance costs. They include interest, insurance, depreciation, and taxes. Obviously, an investor is not going to build a hydro plant if he can place his money in a bank or in bonds and get a return greater than the net revenue from the sale of power after the deduction of operating and maintenance costs. Fixed charges depend entirely upon the first cost of the project. Usually hydro plants are much more expensive to construct than steam plants. Average costs of hydro construction range from $200 to $500 per horsepower of capacity, whereas a steam plant can be built for $100 per horsepower or less.

Hydro plants are not always located at a spot where a natural waterfall existed before the construction of the station. Most sites for development are selected where a stream runs through a deep valley. A dam is constructed across the valley or ravine, from one bank to the other; the water then stores up to the top of the dam, and so has potential energy above the stream bed below the dam. Water is conducted through large conduits from the dam to the powerhouse, where the water runs through the turbines. Sometimes it is advisable to locate the powerhouse at a considerable distance from the dam, and a long flow line or lines of conduit are required to conduct the water. All of this construction increases the cost of the project. In addition, large gates for control of the water and its release during floodtime must be installed, adding still further to the expense.

Frequently, the powerhouse must be located in the middle of the stream, where foundations are insecure unless built with great care and at great expense. Furthermore, it is usually necessary to create an artificial storage basin or pond above the dam, where water can be held for use during the peak demands for power. Some plants have storage enough only to care for the fluctuations in requirements during the day, while in one or two instances there is sufficient storage available to provide for almost an entire season's run. The new Boulder Dam project is of the latter type. Depending upon the topography of the land, considerable areas of flowage land must be purchased when establishing a storage basin. The farmers who are living on or cultivating the ground adjacent to the banks of the stream must be paid for their property if the level of the stream is raised so that it covers their lands.

Location restriction. Of the potential water power in the United States, 40 per cent is available in the Pacific states and 30 per cent in the mountain states. Most of the power used is generated in the eastern part of the United States. Thus, 70 per cent of the water power available

is located where there is little use for power; obviously, then, water power is not always available where it is needed.

Unlike steam plants, which can be located at the most advantageous points, a water-power plant must be located at the site where the energy is available. Some sites are so inaccessible and remote from the market for power that they remain undeveloped because of this factor alone. Usually, long high-voltage transmission lines must be constructed from the hydroelectric plant to the market. The longer the line, the higher the voltage must be; and the higher the voltage, the higher the cost necessitated by the heavier insulators, heavier construction, and larger rights of way.

System of steam and hydroelectric plants. It must not be surmised from this discussion that hydroelectric plants are never feasible. On the contrary, a hydroelectric plant operating as part of a large system will act as a coal-saver. When water is available, steam units can be shut down; and when water is lacking, the entire amount required can be generated by steam. The development within recent years of satisfactory automatic-control equipment for hydroelectric plants has made possible the use of many small and isolated sites where no operator is needed. Plants can now operate entirely without attention, except for an occasional inspection.

Operating efficiencies. Modern steam stations mentioned previously are able to utilize only about 30 per cent of the heat units available in the coal because of the inherently inefficient cycle on which a steam plant must operate. In contrast, modern hydraulic turbines convert more than 90 per cent of the energy of the falling water into electrical energy. Although additional improvements will undoubtedly be made in water turbines, there is little opportunity for any great increase in efficiencies.

Steam station location. It is stated above that a steam plant can be located at the most advantageous point. Nevertheless, there are many factors which determine and limit the location of a steam plant, even though they are not so rigid as the determining factors for hydroelectric plants. If losses in the transmission of energy are to be prevented, generating stations should be located in the center of the load, which, as a general rule, is in the business or industrial center of a large city. But if the station is thus located, we must transport coal from the mine to the plant. Frequently, it is more economical to transport the energy over wires than to haul coal over rails. For this reason, the term "mine-mouth power plant" became popular a few years ago and stimulated the mind of the public to the belief that, within a short while, all generating stations would be moved to the coal fields.

Unquestionably, the factor determining the location of practically every steam plant is water. Not only are considerable quantities of pure water required for boiler make-up, but tremendous volumes are needed for condensing purposes. It is very unusual for a source of usable water to be found in the coal fields, and where this happy combination does exist, a power plant will be found already in operation

As an illustration of the importance of condensing water, there is the

Chicago area, where one of the most highly concentrated electrical loads in the world is established. The generating stations, Fisk Street, Northwest, and Crawford Avenue—all located on the Chicago River—are taking out of that river for condensing the maximum amount of water permitted by the United States Government. Likewise Calumet is using the maximum allowable out of the Calumet River. It is impossible to secure a power-plant location on Lake Michigan, because the entire shore within the City of Chicago is owned by the city for its outer drive and park projects. Consequently, any future power supply must come from outside the city. This fact led to the erection of the supergenerating station State-Line, located on Lake Michigan, as close to the southern boundary of the city as possible, and of a station at Waukegan, beyond the northern limits of the city.

There are other less important factors, such as the cost of the land, which are present in determining the correct location of any industrial plant. Although modern generating stations make little or no smoke, the increased use of pulverized fuel, with its more objectionable sulphur deposits on surrounding territory, in some cases has been an important consideration in the location of a power plant.

Private Versus Municipal Ownership

In 1902, there were 815 municipalities operating their own utility systems. These increased in number until, in 1922, there were 2,581 towns operating such systems. Since 1922, the number of municipal systems has fallen off, in 1937, there were only 1,860 city-owned plants.

In 1902, there were 2,805 privately operated power companies. These increased in number until, in 1917, there were 4,224 separate operating systems. Since 1917, the number of private companies in the power business has fallen; in 1937 there were 1,340 separate systems. This change has been due to consolidations and interconnections for more efficient operation, because in 1917 there were 11,349 cities and towns being served by private companies, as compared to 17,000 in 1937.

One of the drawbacks to the operation of power systems by municipalities is that they cannot logically serve any territory outside their incorporated limits. Nor is the use of power now limited to the city, for the farm also has become electrified. Rural lines extend in all directions from the power plants of private companies and frequently traverse several counties. This is impossible with a municipal plant, for the city taxpayer's money cannot legally be spent for making improvements outside the city.

Government plants pay no taxes, and so withdraw a large amount of profitable property from the assessment rolls. This means that the remaining property owners are taxed more heavily to make up the difference.

Economic Status of the Power Industry

In the United States, during 1937, the kilowatt-hour output of the power industry amounted to 935 kilowatt-hours per person. This figure is exceeded by only three other countries in the world: Norway, with 2,700 kilowatt-hours per capita: Canada, with 2,500 kilowatt-hours per capita; and Switzerland, with 1,900 kilowatt-hours per capita. In Canada, large quantities of energy are consumed in paper mills and similar plants, and in Norway and Switzerland a great amount is used for electrochemical processes.

Figures giving the per capita output for other important countries for 1937 are:

Country	*Kilowatt-Hours*
France	425
Great Britain	675
Germany	400
Japan	440

In 1899, according to the United States Census of Manufactures, each industrial establishment had an average of the equivalent of 49 h.p. in productive machinery; in 1929, this figure had reached 203 h.p. In 1899, the total horsepower available to each worker was 2.14, while in 1929 it was 4.20.

Everyone is vitally interested, directly or indirectly, in the power available in the country, for it determines how much and how long we must work in order to live. The fact that each worker has over 4 h.p. to assist him means shorter hours to do the same work. Because of the more skilled directional efforts required of the workmen, there is a greater margin between earnings and cost of living.

Regulation

The chief reason for the creation of regulatory bodies was to insure adequate and safe service at reasonable and nondiscriminatory rates. The power to regulate property, services, or business can be invoked only under special circumstances. The authority to regulate the conduct of a business rests upon the police power and exists only where the business or the property involved has become "affected with a public interest." Certain properties and kinds of business it obviously includes, such as common carriers, ferries, and telegraph, telephone, water, gas, and light companies.

With the gradual recognition on the part of the public that electric service, to be efficient and economical, must be noncompetitive, came the necessity for some control which, while protecting the utility, would guarantee adequate service at rates that were reasonable and just to all parties concerned. This gave rise to regulatory bodies, or public-service commissions, charged with the enforcement of specific laws and endowed with supervisory and sometimes quasijudicial powers.

The necessity for public-utility commissions is to protect, by regulation, the great public interest in the utilities. The public interest to be protected is not only that of the customer of the utilities but also that of the investor in the utilities. Each needs protection and consideration for both to receive their full measure of satisfaction from utility service. One cannot exist without the other. The customer cannot secure service until the investor provides the money. The investor will not provide the money unless the customer pays such rates as will show ample earnings with which to pay a fair return upon the investment. So, in the interest of the general public, the interests of the investor must be considered in any plan of regulation.

The regulation of public utilities is strictly a legislative function of the Government. This power must be exercised either directly by the state or be delegated to some subdivision of the Government or special agency. Legislatures are not equipped for, nor have they the time to give to, rate-making matters. Such work, therefore, has now been delegated to commissions in most states; and in fixing rates, commissions are acting for the legislatures. In other words, public-service commissions perform strictly legislative functions, delegated to them by the lawmaking bodies.

In most of the states, public-service commissions have wide powers and exercise full jurisdiction over all phases of utility service. They supervise, regulate, and control rates for all classes of service; they define service standards and regulations; they prescribe specific accounting methods; they require periodical reports of financial affairs and physical properties, and prompt records of all accidents; and in many states, they exercise control over the issuance of securities.

While the state may regulate with a view to enforcing reasonable rates and charges, it is not the owner of the property of public-utility companies and is not clothed with the general power of management incident to ownership. The commission is not the financial manager of the corporation and is not empowered to substitute its judgment for that of the directors of the corporation.

There are certain limitations beyond which regulatory bodies cannot go. The utility is entitled to a fair return upon the fair present value of its property. A commission cannot legally regulate rates so far downward that they will not yield a fair return on the fair value of the property in use. If the rate of return described by the regulating body seems so low that it is less than a fair or reasonable return on the value of this property, the possibility of appealing to the courts is always open.

Generally speaking, the commission's right to establish rates arises only where, after a hearing and upon evidence, it is found that an existing or proposed rate is unjust and unreasonable or otherwise unlawful. A rate which returns more than enough to escape the charge of confiscation is not on that account extortionate or unreasonable

There is no uniform rate of return which always and under all circumstances must be adhered to. The courts have held that a utility is

entitled, as a minimum, to such rates as will permit it to earn a return on the value of the property which it employs for the convenience of the public equal to that generally being made, at the same time and in the same general part of the country, on investment and other business undertakings which are attended by corresponding risks and uncertainties. The rate must be sufficient to yield the amounts required to pay taxes and proper operating charges, depreciation, and a sum sufficient to constitute just compensation for the use of the property employed and the service furnished. The return should be reasonably sufficient to assure confidence in the financial soundness of the utility and should be adequate to maintain and support its credit. It should attract an adequate flow of capital for investment purposes to the particular utility and maintain the integrity of the investment, so made, so that the utility may secure ample capital to build and extend its physical properties in anticipation of the requirements of the territory and customers served by that particular utility.

Electric Rates

Electric service, unlike commodities, must be delivered to the customer at the point of consumption in whatever quantity desired at the very moment the switch is turned. There can be no delay in delivering the purchaser's requirements, no leisure in manufacture. There can be no intervening jobber, middleman, or merchant. The whole sequence of economic process, from initial manufacture to consumption, is practically instantaneous.

The question of the rates paid for utility service is, of itself, a very small part of the problem of utility regulation. It is of far more importance to the public to secure all the utility service it needs when and where it wants it than to pay a rate a fraction more or less for this service, provided always the rate is reasonable.

A rate is a reasonable rate when, on the one hand, it does not exceed the value of the service rendered, and, on the other hand, is sufficient to pay operating expenses, including maintenance, depreciation, taxes, etc., and a reasonable return on the fair value of the property used and useful in the public service. A rate between these two points is reasonable to the public and the consumer and offers a fair incentive of reward to investors in the utility.

The opening of the first commercial electric central stations in 1882, both in the United States and in England, immediately presented for solution the problem of determining proper charges for the service rendered to the customers. In opening the Pearl Street plant at New York City, Thomas Edison offered service to the original 59 customers for several months without any billing, pending study and adjustment of what should be considered reasonable charges.

The only meters at that time were devices recording the total time a current existed in an electric circuit. Between 1880 and 1882, Edison invented two principal types of meters, one a motor meter, which did not

appeal to him and was never manufactured commercially, and the Edison chemical meter. The latter was formed by placing two pieces of zinc into a glass jar containing a solution of zinc chloride. Current flowing from one zinc to the other through the solution caused particles of zinc to be transferred from one to the other. The amount of current used was measured by the loss of one and gain of the other. This was found to be substantially accurate and was in common use by the large companies from the early eighties until about 1900.

The energy was all used for lighting, and there was but a single class of customers. The first meter rates were straight-line rates at so much per kilowatt-hour, and the service was sold on its merits for what it would bring. In the early eighties, it was difficult for companies to make both ends meet with a rate of 25 cents per kilowatt-hour. The making of rates was little influenced by theory.

So long as the use of the energy by the different customers and the equipment required to serve them were substantially similar, it was unnecessary to differentiate between them to avoid discrimination. As new ones began to develop and the electric light and power industry began its real growth as the servant to homes, stores, and factories alike, it was found that the only way to prevent one general class of customers from carrying part of the cost of serving the other classes was to have rates made to conform as closely as possible to the actual cost of the service to the class.

Neither the equities nor the expediences require that the rate schedules shall be meticulously exact. It is not required that every kilowatt of reservation for a customer shall earn identical annual return, nor that every kilowatt-hour sold shall carry the same margin of profit. The rule is that everyone shall be served at such a price that none shall be served at the cost of another and that no one shall be asked to pay an excessive profit.

The determination of class costs calls for an analysis of expense over and above that contained in any state or association classification of accounts. The principles of such analyses have been published many times. The differences in practice are many, and the possible refinements are legion. The first essential is a separation of all costs (including capital costs) into the three basic cost classes: costs varying with the number of customers served, costs varying with demand (or maximum amount used during a predetermined short period) and costs varying with the use of the energy.

The emergence of demand charges as separate elements in electrical rate schedules is due to causes characteristic of electric supply, rather than to the very general distinction between necessary running expenses and expenditures for carrying and maintaining capital.

Well-designed rates, based upon experience and sound principles, are the greatest factors in the development of larger sales. Poorly designed rates will render futile the efforts of the best salesmen. To be successful rates must be promotional.

The promotional form of rate is by no means new. It apparently had

its origin more than 25 years ago, when Wright and Hopkinson designed the forms of rates which still bear their names. Neither of these rates was originally intended primarily for residence service, although the Wright demand rate was extensively used for general lighting purposes where the cost of a demand meter was not prohibitive or where the demand could otherwise be satisfactorily determined.

All of the rate forms which give recognition to customer-demand requirements and time element, and are thus promotional, have the common purpose of simplifying metering and wiring cost, elimination of improper connections of appliances under a multiple-metering system, reduction in accounting cost, and, further and more fundamental, closer relation between costs and revenues, thereby reducing the number of unprofitable customers and stimulating additional use. Such readjustments of rates to cost with respect to small customers is not an arbitrary act but is in recognition of the legal rights of customers, established by statutes, the commissions, and the courts, to relief from unreasonable burdens arising from other unprofitable customers.

Capitalization not a factor. Since the passage of the modern public-service commission laws, in 1907, the capitalization of the public utilities has not been a factor in the determination of reasonable rates. The value of the property used and useful for the service to the patrons forms the basis on which the charges are to be computed. As one of the important commissions has stated:

> It does not make the slightest difference whether the issued capital stock is "watered" or not, nor to what extent the "water" may be present. The injection of "water" cannot add one cent to the value of the property which is actually used, and that is the only inquiry which the commission is interested in.

Utility management has no function or responsibility of greater importance than that of rate-making. Earnings depend upon the prices charged for the services rendered. The successful development of greater sales depends upon the flexibility of the rate schedules and their adaptability to new uses for electricity, to changing costs of production and distribution, and to competitive conditions in the field of power sales.

The relations between a utility and the public it serves are influenced to a large degree by the rates, their amount, their structure, and the presence or avoidance of unjust discrimination in their application.

Successful utility management appreciates fully the reaction of the public to promotional rates. Experience has demonstrated the relation between low rates and increased use by residence and commercial customers. While there is a definite limit beyond which management cannot go in rate-making—namely, the cost of the service—the management should do everything in its power to make its rate schedules the most efficient aid in developing business. Successful management is not so short-sighted as to neglect any opportunity to increase sales, because this means greater volume of output and, in turn, lower unit costs. Through lower costs lies the safe, clear road to even lower rates.

The major items of cost in residence service are fixed charges directly applicable to the customer's required demand for items actually chargeable to his service, such as billing, metering, and so forth. Together, these comprise the greater part of his cost, and they do not vary from month to month, as may his use of energy.

Taxes

Mention should also be made of the tax situation. Taxing bodies are looking more and more toward utility companies for funds, and tax burdens have shown the largest rate of increase of any items entering into utility operation. In 1902, taxes amounted to 3.4 per cent of the operating revenue; while in 1939, they equaled 16.2 per cent of the revenues of that year. Total taxes paid in 1939 by utility companies amounted to $350,000,000. It might even be said that, at the present time, electric companies work principally for the Government, rather than for their creditors, the bondholders, or for their owners, the stockholders, according to the 1939 income statement of the electric light and power industry. For the first time, taxes exceeded stockholders' dividends; since 1937, they have exceeded interest payments. In 1939, electric operating companies paid out in taxes $350,000,000, or one dollar out of every six received from consumers. This is $70,000,000 more than the $280,000,000 in interest and amortization charges applicable to electric operations of private companies, and about $25,000,000 more than dividends computed on a similar basis.

In the long run, increased taxes can serve only to increase the rates charged the consumers, for no utility can survive indefinitely unless it shows a profit.

Financing of Utilities

One of the important characteristics of the power industry is the enormous investment in physical facilities necessary. A utility has an extremely low rate of capital turnover, as can be strikingly shown by comparison with a typical manufacturing business. It is not uncommon for a mail-order house to turn over its capital three times during the year. On the other hand, the typical power company has annual sales amounting to from one fourth to one fifth of its capital, or, in other words, a turnover once in 5 years.

On December 31, 1939, the power industry had an investment in plant and equipment of about $13,000,000,000 and gross revenues of $2,330,000,000. The investment values of the industry are surpassed only by those of agriculture, railroads, and the oil industry. The growth of the utility industry can be seen from the figures of 1912, when $2,000,000,000 were invested and the total revenues were $302,000,000. Thus, in 27 years, the industry increased its investment more than six times and its revenues almost eight times.

Ordinary manufacturing businesses finance their program of expansion largely through the use of surplus earnings. Utilities are fundamentally different, because commission regulation will not permit rates to be charged above a reasonable return upon the investment, and consequently the use of earnings to construct additional plant can be done only at the expense of the stockholders.

In earlier years, before the depression reduced the rate of utility expansion, a very large amount of new financing was necessary every year. During the decade from 1922 to 1932, the operating electric light and power companies sold to the public about $4,000,000,000 worth of stocks and $3,750,000,000 of bonds. All of this went into new construction, as indicated by the increase in the value of plant and equipment of $7,895,000,000, or from $4,230,000,000 at the end of 1922 to $12,125,000,000 at the end of 1932. A present, the annual appropriations for depreciation and retirements are larger than the actual amounts of property retired, and the balance is available for investment in plant extensions. During the recent years of small-plant expansion, practically all funds necessary for new construction have been obtained from the re-investment of depreciation reserves, from net earnings withheld from stockholders, and out of previously accumulated surplus.

29

The Shipbuilding and Shipping Industries*

This chapter, although it includes shipping in its title, is confined to water-borne transportation of persons and merchandise in commerce, and emphasizes the essential function that shipbuilding performs in providing the vessels for such transportation.

Shipping occupies an important position in the commerce and general prosperity of a nation. Foreign trade and shipping are closely related. It is a matter of history that maritime nations, as their shipping has grown have usually enjoyed a growth in their trade, and that those countries that have neglected the development of sea power have not long maintained an important position in the family of nations This relation between trade and shipping is not generally recognized.

The purpose of this chapter is to present in some detail the important function that shipping performs and to trace the development of shipping and shipbuilding in the United States.

Several words and terms as applied to the subjects discussed are used in their technical significance, and their meanings are defined in the glossary to be found at the end of the chapter.

History of Shipping

Early history of shipping. Navigation is as old as civilization. It is probable that the secret of navigation was discovered by the early cavemen in observing floating objects blown by the wind or drifting with the current of streams, and that they early learned that, by sitting astride a log and using their hands as paddles, they could control to some extent their direction of motion and their speed through the water. The next discovery, it may be conjectured, was the raft, consisting of two or more logs crudely fastened together to avoid the rolling effect of a single log. The early boat was probably a very crude and simple craft, made from a log roughly hollowed out by a process of burning and then scraping to enable it to carry a person or an object.

Archeological research in the Valley of the Nile has brought to light the existence of a primitive boat dating from 4,000 years B.C., believed to have been propelled by a small, square sail and steered by an oar. It is certain that boats with sails were in use on the Nile several thousand

years B.C. The Phoenicians are credited with the first development of sailing vessels of sufficient size to carry on reasonably safe commercial operations on long sea voyages.

Until the beginning of the nineteenth century, all vessels, from the smallest to the largest, were built of wood and were propelled either by oars or by sail.

Warships, although fitted with sails, were equipped with oars as an auxiliary power until late in the sixteenth century. In the naval battle of Lepanto, fought between the Holy League of Christian Mediterranean nations and the Turkish Mohammedans, in 1571, both contestants furled their sails and fought with their ships manned by oars, using their ships essentially as floating platforms. Only 17 years later, in 1588, the first recorded naval battle fought under sail was between the Spanish Armada and the British fleet.

From the earliest days of navigation to the beginning of the American colonial period, the improvement in ship design was very gradual. Vessels increased somewhat in size and improved slowly as to their form, safety, comfort, and speed. However, the majority of merchant vessels constructed prior to the colonial period, and for many years thereafter, did not exceed a carrying capacity of 200 tons.

With few exceptions, improvement in the art and science of shipbuilding has been by a slow process of evolution. The step from manpower to sail was the only revolutionary advance until recent times. The general adoption of steam power in place of sail, iron in place of wood, the screw propeller in place of the paddle wheel, the application of electricity to ship uses, the introduction of the steam turbine and the internal-combustion engine for specific services, and the use of welding instead of riveting in ship construction have all taken place since the beginning of the nineteenth century.

Shipping during the colonial period. When the first colonists landed on American shores, the country was a vast, trackless forest inhabited only by Indians, whose attitude toward the whites was entirely uncertain and who more often than otherwise proved to be unfriendly.

The navigation of rivers, bays, and sounds was the safest means of traveling from one settlement to another and the best means of conducting trade. The only connection the colonists had with the homeland was by means of ships. Under such conditions, the necessity for ships was recognized, and shipbuilding was commenced almost immediately at the time of the settlement of the colonies. It is recorded that the ill-fated Popham Colony, on the coast of Maine, built a vessel in 1607 known as the *Virginia*, a "fair pinnace of 30 tons" in which they sailed across the Atlantic.

All of the early settlements were on or near the seaboard, and small boats were constructed in all of the colonies for the transportation of persons and property between the settlements and for fishing.

Trade between New Amsterdam (New York) and New England was opened as early as 1627, when the Dutch invited "friendly commercial relations" with the Pilgrims by sending the governor of the colony a

rundlet of sugar, two Holland cheeses, and a letter offering to give credit. At first, the Pilgrims were not responsive to this invitation, because the Dutch were trading with the Indians in Connecticut, a region claimed by England; but in 1633, Governor Winthrop's vessel, the *Blessing of the Bay*, visited New Amsterdam and established relations so cordial that, by 1635, New Amsterdam vessels were carrying to Boston tobacco and salt from the West Indies and Virginia, and Flanders mares, oxen, and sheep from Holland.

The first vessel recorded to have been constructed in América for trade between the colonies and their homeland was built in 1631. Within a period of 50 years thereafter, the colonies had nearly 1,000 vessels, the largest of about 250-ton capacity, engaged in domestic and foreign trade and in fisheries The first schooner type of sailing vessel was built at Gloucester, in the New England colonies, as early as 1714.

In early colonial days, only the bare necessities of life could be obtained in the new settlements. Communication with distant lands, and particularly with the West Indies, was essential to secure sugar, cotton, rum, indigo, and other commodities, in exchange for which the colonists shipped fish, lumber, horses, cattle, and agricultural products.

At this period Spain, France, and Great Britain were rivals for the ownership of the West Indies and for the control of their trade. This keen competition resulted in open piracy in the vicinity of the islands, to which colonial vessels fell a frequent prey.

The West Indian trade was so important to the colonies that it stimulated American shipbuilding ingenuity to build the staunchest and fastest vessels afloat, which constituted a commercial inheritance that was enjoyed by later generations.

The whaling industry contributed greatly to the development of a merchant marine in colonial days. Whales were to be found in great numbers along the sandy beaches of Cape Cod and Long Island. Whale oil was in demand, and the catching of whales for the extraction of oil was a lucrative, although hazardous, business in which both English and Dutch settlers early engaged and which became a systematized and established industry.

The early whale boats were modeled after Indian canoes, sharp and double-ended, and were kept upon the beach until whales were sighted. As the industry grew, whales became scarce along the shores, requiring larger boats capable of going greater distances to sea to capture them. As a consequence, at the beginning of the Revolution, the American whaling fleet was composed of more than 300 vessels aggregating about 33,000 gross tons and employing approximately 5,000 seamen They sailed, not only along the Atlantic Coast, but even into the Arctic regions, and remained at sea for long periods, sometimes 2 years or more.

Great Britain, Spain, France, and Holland had enacted navigation laws which largely restricted the carriage of their foreign trade to their own vessels. By reason of these laws, the navigation of vessels owned by the colonists was curtailed in foreign trade, not only with the West Indies,

but elsewhere throughout the world. These laws continued in force until after the beginning of our existence as a nation.

Shipping during the early national period. When the American colonies won their independence in 1783, their merchant ships, of course, lost their British nationality and became foreign ships to Great Britain. American trade with the West Indies was prohibited and was elsewhere subjected to restrictive and discriminatory treatment by foreign nations because, although we had a national flag, we did not have a strong unified national government to support and promote foreign commerce.

The colonists had developed a lucrative trade with the Far East notwithstanding the fact that their mariners had no protection on which to depend but their own courage and the speed of their vessels, while in the same trade, the British and Dutch received the protection and support of their national governments. At the beginning of our national history in 1789, however, we had but 123,893 gross tons of shipping engaged in foreign commerce, the equivalent of not more than 10 or 12 modern ships of moderate size.

Recognizing the national importance of our foreign trade and shipping, Congress, at its first session in 1789, passed the Tariff Act of that year, which imposed discriminatory customs duties in favor of goods imported into the United States in American flagships, wholly owned by citizens of the United States, by providing a 10 per cent discount of customs duties on all such goods entering this country and imposing higher duties than otherwise provided in the act on teas brought in by foreign vessels. This discrimination made it almost impossible for foreign vessels to engage in the tea trade. In the same year, another act was passed imposing higher tonnage dues on foreign vessels than on American vessels entering American ports.

Five of the first 11 acts passed by Congress contained provisions to encourage and regulate American shipping, and from 1789 to 1830 no less than 50 acts affecting shipping and trade were passed. As a result of this helpful legislation, the growth of American shipping from 1789 to 1807 was without parallel in the history of the commercial world, and the era from 1789 to 1828 is known as the "Golden Age" of American water-borne commerce. We carried at one time during this period as much as 90 per cent of our foreign commerce in our own ships. Our foreign trade and shipping provided a means of highly profitable employment for shipowners and operators, and was the source of many early American fortunes. Our people, during this time, were ship-minded and recognized the importance of shipping to our national prosperity.

The growth of our shipping was not, however, without its setbacks. Great Britain continued to restrict our trade with the West Indies. Piracy continued on the high seas, not only in the waters of the West Indies, but also on the Mediterranean and along most of the established trade routes. In 1791, Congress authorized the building of six naval frigates to suppress the Barbary pirates and otherwise protect our commerce. These vessels were the first ones built for our American navy. During the Napoleonic Wars in Europe, there was impressment of

American seamen by the belligerent nations, and in some instances they seized and commandeered American vessels.

Shipping during and after the War of 1812. Our second war with Great Britain, 1812 to 1815, caused a further interruption in the growth of our shipping, but it stimulated our seagoing spirit, and the period following the war showed a rapid growth in American shipping and American trade. In fact, we became so well established upon the seas that Congress felt that the discriminatory legislation which had been enacted for the protection of American vessels was no longer necessary. As a result, the United States and Great Britain, in 1815, bound themselves by treaty not to impose discriminatory duties on products carried in trade between these countries. While intended to apply to British colonies as well as to Great Britain itself, the treaty did not come into full force as regards the West Indies until 1849.

The treaty of 1815 led to treaties with other nations with the object of eliminating tariff legislation of a discriminatory character. These treaties were followed gradually by a repeal of most of the previous discriminatory duty acts, the last of which was annulled in 1828. One very important section of an act passed in 1817 restricted our coastwise trade to American-owned and built vessels, an act which is in force at the present time.

Notable developments in shipping from 1789 to 1860. Credit for the first steamship to engage regularly in service is given to Robert Fulton, who built the *Clermont*, a paddle-wheel vessel which was first operated in 1807 on the Hudson River. However, before that date experiments on the application of steam to the propelling of ships had been conducted by both American and foreign engineers for many years.

The development of early American steamship lines as commercial ventures was delayed for about 20 years because several states had granted to their citizens the exclusive right to operate steamships upon their waters. Such rights were given by New York, Connecticut, New Jersey, and other states. However, in 1824, in a celebrated decision, the Supreme Court of the United States decided that, inasmuch as Congress had power under the Federal Constitution to regulate commerce, it also had the power to regulate navigation and that Federal regulation of all navigable waters must, therefore, apply. This decision resulted in the death knell of the monopolies which had been granted by the States in the operation of steamships and was followed by a rapid increase in the number of steamships in our harbors, on our rivers, and along our coasts.

Sailing-ship service across the Atlantic, until 1818, was intermittent. It was in that year that certain enterprising American owners established the Black Ball Line, with regular scheduled sailings between New York and Liverpool. Vessels of this line sailed on the first and sixteenth days of each month throughout the year and continued in service for nearly 40 years. They were sailing packets, each of less than 400 tons carrying capacity, and required from 25 to 40 days to make the passage. The eastern trip was called the "downhill" trip, and the western the "uphill," because of the prevailing winds which made the eastern passage faster.

In 1819, the *Savannah*, a sailing vessel equipped with an auxiliary steam engine, built at Corlears Hook, New York, undertook the voyage from Savannah to Liverpool and to St. Petersburg and return. While the *Savannah* is regarded as the first steam-driven vessel to cross the Atlantic, it should be remembered that her engines were used for only a small part of the trip. Because of her inability to carry sufficient fuel for a transatlantic trip, it was necessary to proceed a great part of the way under sail. This trip of the *Savannah* was largely an experiment and was not followed by a regular transatlantic service under steam power until 19 years later, when two British vessels, the *Sirius* and the *Great Western*, inaugurated such a service, which was followed by the Cunard Line in 1840.

From 1846 to 1850, transatlantic steamship service was inaugurated in the United States by the Ocean Steamship Company, the Collins Line, the Pacific Mail, and other companies as a result of the impetus given to shipping by the Ocean Mail Acts of 1845 and 1847. American steamships continued to ply the oceans until 1858, when the services were largely discontinued because of the repeal of those acts.

The whaling industry, which began in colonial days, continued to grow until the days of the Civil War, when it reached a total of 200,000 gross tons of shipping.

Clipper-ship era. Although the steamship for commercial purposes was being developed in the United States early in the nineteenth century, the sailing vessel was predominant until near the end of the century. The middle of the century was marked by the development of the famous clipper ships. These were seagoing sailing vessels built of wood, rigidly constructed for a maximum sail area, and of such form as to secure greater speed than the earlier models of sailing vessels. The clipper was the outstanding development in the evolution of the sailing vessel. It approached its perfection of design about 1843 and reached its peak of performance during the fifties.

The discovery of gold in California in 1849 gave a tremendous impetus to the building of fast sailing vessels to carry men and supplies around the Horn to the California coast. The discovery of gold in Australia, in 1851, also created a demand for the clipper ship, as did likewise the increasing trade with the Far East. These ships were so successful that many of them were chartered or purchased by citizens of foreign countries for trade between the Far East and Europe, and later for use as transports by Great Britain and France during the Crimean War.

The story of our shipping during this period is replete with feats of famous captains and shipbuilders, and notable performances of clipper ships. While there are many of them, a few outstanding records illustrative of this period are taken from Mr. Carl C. Cutler's *Greyhounds of the Sea* and are given in Table I.

The Civil War seriously interrupted the development of our merchant marine and marked a rapid decline of the use of the clipper ship. Many of our ships, both steam and sail, were commandeered for war service. Others were sold abroad to escape possible capture or plunder, or because of the interruption of trade.

TABLE I

RECORDS OF TYPICAL FAMOUS CLIPPER SHIPS[a]

Clipper	*Captain*	*Year*	*Run*	*Time*	*Builder and Year of Construction*
Ann McKimm	Joseph Martin	1838	Valparaiso to New York	53 days	Mennard & Williams, Baltimore, Md., 1833
Sea Witch	R. H. Waterman	1849	China to New York	74 days—14 hours	Smith & Dimon, New York, N. Y., 1846
Flying Cloud	J. P. Cressy	1851	New York to San Francisco	89 days— 8 hours	Donald McKay, East Boston, Mass., 1851
Challenge	John Land	1852	Point Opposite Coast of Japan to California	18 days	Wm. H. Webb, New York, N. Y., 1851
Northern Light	Freeman Hatch	1853	San Francisco to Boston	76 days— 6 hours	E. & H. A. Briggs, South Boston, Mass., 1851
Witch of the Wave	Benjamin Tay	1853	Calcutta to Boston	81 days	George Paynes, Portsmouth, N. H., 1851
Sovereign of the Seas	Lauchlan McKay	1853	Sandwich Islands to New York	82 days	Donald McKay, East Boston, Mass., 1852
Flying Scud	W. H. Bearse	1854	New York to Marseilles	19 days—20 hours	Metcalf & Norris, Damariscotta, Me., 1853
Comet	E. C. Gardner	1855	San Francisco to New York	76 days	Wm. H. Webb, New York, N. Y., 1851
Andrew Jackson	Johnson	1860	Liverpool to New York	15 days	Irons & Grimmell, Mystic, Conn., 1855

[a] Among the clipper ships which sailed from New York around the Horn to San Francisco within the unusual time of 100 days are the following well-known vessels: the *Antelope, David Brown, Flying Fish, Golden Gate, John Gilpin, Romance of the Seas, Sea Witch, Surprise, Sword Fish,* and *Witchcraft.*

The *Dreadnaught*, which was built by Currier and Townsend at Newburyport, in 1853, and commanded by Captain Samuel Samuels, maintained a regular schedule for years between New York and Liverpool. Her first eight passages westward averaged only 24½ days. Cutler does not authenticate, however, a reported crossing of the Atlantic eastward by this vessel in 9 days and 17 hours.

The introduction of iron in shipbuilding. Until the Civil War, shipping in the United States had prospered with sailing vessels built of wood. Our forests adjacent to the seaboard furnished an almost unlimited supply of various woods suitable for shipbuilding purposes, such as tall, straight white pine for masts; white oak, hackmatack, and locust for ribs; yellow pine for keelsons and ceiling timbers; white pine for floors; and live oak for aprons. Labor costs in the United States were somewhat higher than abroad, but because of the availability of shipbuilding material at low cost, the United States could build merchant vessels as cheaply as Great Britain and other foreign countries.

For centuries, shipbuilding had been the basic industry of Great Britain and an important industry in several Continental European countries. Ships in those countries were built of wood, and the supply of European timber suitable for shipbuilding had been largely depleted, with the result that much of this material came from the United States and Canada. Great Britain became apprehensive of the effect of her dependence upon other countries for shipbuilding material and began to develop the use of iron instead of wood. She had ample deposits of iron ore and of coal for the conversion of the ore into materials suitable for shipbuilding.

Although experiments in the use of iron in the construction of small barges had been carried on before the close of the eighteenth century, the first iron ship, the *Aaron Manby*, a small paddle-wheel steamer about 50 feet long, was not built in England until 1821. British-built iron ships for ocean service began operations in 1838 but were not regularly engaged in transatlantic service until the fifties.

While the development of iron shipbuilding in the United States lagged behind its progress in Great Britain, nevertheless three iron vessels—the *Ashland, Ocean,* and *Bangor*—each about 100 feet long and of 200 gross tons, were constructed at the plant of Betts, Harlan, and Hollingsworth in Wilmington, Delaware, in 1843 and 1844. The general adoption of iron for shipbuilding in the United States did not take place until after the Civil War. The first large American-built iron ships to engage in transatlantic service were the four vessels of the American Steamship Line—the *Ohio*, *Pennsylvania*, *Indiana*, and *Illinois*—each of about 3,100 gross tons, built at the works of the Cramps Company in Philadelphia, completed during 1872 and 1873.

The transition, at this time, from wood to iron in shipbuilding gave Great Britain a distinct advantage over the United States, owing to the fact that she had developed her iron industry by the establishment of well-equipped iron mills.

It was not until 1900 that one half of the merchant vessels built and registered in the United States were being constructed of iron or steel. The use of steel as a material for shipbuilding having been found practicable, it soon displaced iron because of its superior qualities, which permitted its use in the construction of vessels of equal strength but weighing much less than those constructed of iron.

Decadence of American shipping in foreign trade. The period between the Civil War and the World War marked a continuous decadence in our merchant marine in foreign trade, although our coastal and Great Lakes fleets showed a gradual but continuous growth. This decadence was due to the greater cost of operation of American vessels than of foreign vessels, brought about largely by the greater cost of ship construction by the United States as a result of the adoption of iron and steel.

Another transition was in progress in the United States which militated against a merchant marine. The increase in our population, followed by the enlarged demands of our domestic markets, the development of our great natural resources, the opening of the Western states into new farmlands, and the growth of our manufactures and agricultural pursuits—all tended to divert the energies of our people away from the sea to internal commercial activities and to make them less ship-minded.

From time to time, numerous efforts were made by Congress to revive our shipping by legislation. In the sixties, in the seventies, and again in 1891, the Postmaster General was authorized to enter into contracts with ship operators for the carriage of mail to foreign ports. While these legislative acts brought about the building of a few ships, which were operated in foreign trade for a short period, the ventures were not profitable, and the services were afterward largely discontinued. Whaling, which reached its peak at the beginning of the Civil War, declined rapidly thereafter, so that at the present time a whaling vessel under the American flag is rarely seen, although this industry under modern methods is now extensively carried on by the Norwegians and to a lesser degree by other nations.

First World War period. The First World War gave a tremendous impetus to American shipping and shipbuilding. Immediately upon the entry of European nations into the war in 1914, foreign vessels, which at that time carried nearly 90 per cent of our foreign trade, were largely withdrawn from usual trade routes, and as a result, the United States was left without sufficient means to ship its goods to foreign markets. The few foreign vessels which were then available for the shipment of our domestic products to foreign markets restricted their cargoes to those products of which their respective countries were in immediate need. Thereby the normal avenues of foreign trade through which our exports and imports had been carried during times of peace were, if not closed, so curtailed that the products of the industries of the United States available for export could not be disposed of. Miles of railroad tracks were encumbered with freight cars loaded with products awaiting shipment to foreign markets, and many domestic factories were closed because of their inability to secure imports necessary to the manufacture of their products. These conditions imposed an enormous loss upon the people of every section of the United States and made them appreciate, as never before, how essential an American merchant marine is for the nation's business.

When the war had been in progress only a few months, American

shipyards received orders for a large number of new ships from both American and foreign shipowners. The demand for new tonnage was so great that new shipyards were constructed at abnormal costs, engineering and designing staffs were organized, and mechanics whose training qualified them to build ships were promptly assembled.

Realizing the serious lack of American shipping facilities and the great financial loss that it was imposing upon the people Congress passed the Shipping Act of 1916, the purpose of which was to encourage, develop, and create a naval auxiliary, naval reserve, and a merchant marine, in order to meet the requirements of the commerce of the United States with its foreign territories and possessions, and with foreign countries, and to regulate shipping. To accomplish these purposes, the act created the United States Shipping Board.

The act authorized the Board to form a corporation for the purchase, construction, equipment, lease, charter, maintenance, and operation of merchant vessels in the commerce of the United States. The total capital stock of this corporation was not to exceed $50,000,000. The Shipping Board, in compliance with the act, incorporated the United States Shipping Board Emergency Fleet Corporation. All the capital stock of the Corporation, except qualifying shares of the trustees, was to be owned by the United States.

On April 6, 1917, the United States entered the First World War and immediately thereafter inaugurated a merchant shipbuilding program to the maximum of its capacity for the purpose of providing vessels for the transportation of food, munitions, and supplies to the seat of war and to replace those which had been destroyed by the enemies' submarines, mines, and sea raiders. This program to build new ships and to operate them was carried on by the Emergency Fleet Corporation under the supervision and control of the Shipping Board.

In 1916, not more than 22 shipyards were building steel seagoing vessels in the United States; but in 1918, 211 shipyards were constructing such vessels of steel, wood, or concrete. As a result of this shipbuilding program, which was not completed until after the close of the war, the United States owned not less than 2,300 merchant vessels, notwithstanding that many contracts for the construction of merchant vessels were canceled by the Emergency Fleet Corporation shortly after the Armistice.

Period following the First World War. During the First World War, industrial plants of the United States had greatly increased their facilities. Farmers had increased their output of agricultural products, not only by planting new acreage, but also by the use of improved machinery. At the close of the war, our industries, including agriculture, were producing more than was required for home consumption, and as a consequence, the extension of foreign markets for the sale of surplus products became a national problem. Other countries had also increased their facilities in many lines of industry and were confronted with a problem similar to that of the United States in the disposition of their surplus.

Now that the United States owned its large fleet of war-built merchant

vessels, the question naturally arose, "Why not use these vessels for the carriage of our surplus products to foreign markets, encourage the development of those markets, and thus lay the foundation of an American-built and American-owned merchant marine, and thereby reëstablish the United States in the carriage of a substantial part of its merchandise to foreign markets?"

Legislation Affecting the Industry

Merchant Marine Act of 1920. Congress, aware of the new postwar trade opportunity and its importance to our industrial prosperity, enacted the Merchant Marine Act of 1920. The United States Shipping Board was directed to develop and encourage the maintenance of a fleet of American commercial vessels suitable and sufficient to carry the larger part of our commodities in foreign trade and to serve as naval or military auxiliaries in case of national emergency. The Shipping Board soon established shipping services in the more important trade routes. Some services were operated directly by the board, while others were managed privately under contract with the board and later were sold to private operators.

The establishment of new shipping services under the American flag coincided with the beginning of a tremendous growth in our foreign commerce. Our water-borne business increased continually from $5,985,000,000 in 1922 to $8,129,000,000 in 1929. Measured by volume, our overseas foreign trade in 1929 was 108,460,000 long tons, of which American vessels were credited with carrying 43,152,000 long tons, or about 40 per cent.

The character of our export trade changed substantially after the First World War. Whereas before the war agricultural products constituted 54 per cent of our export trade, the change in world affairs so altered our business that, shortly after the war, 63 per cent of our exports were of manufactured and semifabricated materials and only 37 per cent were agricultural products. In 1939, the figures were 87 per cent and 13 per cent, respectively.

In the decade following 1929, dislocations caused by political and nationalistic policies and the general depression in business that prevailed throughout the world affected the export and import trade of all nations, our own foreign trade plummeting to the low figure of $2,933,790,000 in 1932. Inauguration of important trade treaties which tended to offset unfavorable tariff barriers and a general improvement in business conditions throughout the world have since aided the rebuilding of American foreign trade, which for the United States, at the end of 1940, aggregated $6,647,009,000.

Government aid to shipping. As a public necessity which governments over the world have found desirable to support and encourage for the general welfare of their citizens, shipping becomes part of national policy Exporting and importing are different from other types of business because, while it is privately conducted, foreign trade remains

national in character and competes with the trade of other nations. Our products for sale as well as our necessary purchases must meet the challenge of other national groups, many of whom are well-subsidized by their governments. The part commercial craft plays in national policy and defense became more evident as the European conflict, which began in the fall of 1939, was intensified. Efforts to retain our neutrality by prohibiting our shipping from plying in war zones and the increment of our trade with nations not involved in the war show the extent to which our vessels and our shipping policies affect our entire business life. More enlightened opinion in recent years, which prevailed after our sad experiences in the First World War, managed to hold together our merchant marine on a fair scale at least, so that, in 1940, approximately 25 per cent of our commerce by volume was borne by our own ships, as compared with less than 10 per cent at the outbreak of the war in 1914.

In the competition between American and foreign merchant vessels, the United States suffers severe handicaps because of the greater construction cost of ships built in the United States, due principally to higher labor and material costs reflecting the higher standing of living, as compared with those built abroad. In the operation of ships, our crews and officers are paid much higher wages and are better maintained and housed than those of most other nations. The most serious handicaps, however, are those of initial ship costs, which determine charges for interest on investment, insurance, and depreciation.

Around 80 per cent of the cost of building an oceangoing vessel is involved in wages, which, in the United States, are again by far the highest in the world. These wages are directly reflected, not only in the cost of work in constructing a vessel in the shipyard, but also in the prices paid to makers of material and equipment. Needed materials come from every state, and the services of upward of 40 crafts are used in the shipyard.

Other factors resulting in higher costs of shipbuilding in the United States than those prevailing abroad are due to more elaborate owner and Government contract and specification requirements, among which are greater subdivision of ships, greater safety from fire and other increased safety of life-at-sea requirements, more elaborate plans, higher cost of inspection, higher costs due to social legislation and other acts of Congress, and many others. However, if we eliminate these higher requirements of American ships and take into account the relative labor rates in this country and abroad, shipbuilding costs here compare favorably with foreign costs.

American efficiency is fully maintained in the building of ships at costs which cannot be compared with those prevailing in mass-production industries, such as the automobile industry Shipbuilding is a highly specialized industry; automobile building a highly mechanized industry. Every ship is a single specialized product, from the time of its inception in draft form to the first trial run, with never more than a very few produced from the same plans. Automobiles, on the other hand, are

produced in great numbers, sometimes as many as 1,000,000 from the same design. Where ships are constructed in lots of five and six from the same design, as occasionally occurs, the average price per ship has been reduced from 12 to 15 per cent under the price for one vessel only, showing the distinct saving that can be made in the production of any article when produced in quantity.

Ship design. There has been a great improvement throughout the world in the design of ships since the First World War. Improvement in ship form and improvement in the design of both main and auxiliary machinery have greatly increased the efficiency of operation; and while the cost of shipbuilding has increased, ship operators are getting a much better ship with less fuel cost per horsepower, more cubic space per ton of displacement, greater safety of operation, and more comfort for the officers and crew. The speed of cargo carrying ships has gradually increased since the war, but *with greater economies of operation, it is safe to say that three ships of the same size can do substantially the same amount of work as four ships of pre-1914 design.*

Merchant Marine Act of 1928. The art and science of shipbuilding, like that of other industries, is continually changing. The value of ships depreciates with age, to some extent from deterioration and to a greater degree from obsolescence. New ships incorporate new requirements and greater economies, so that the average useful life of a ship, particularly in foreign trade, in competition with the vessels of other nations, is about 20 years. Any shipping program, therefore, requires a shipbuilding program as well

While the Merchant Marine Act of 1920 resulted in the creation of many new services to foreign markets, it did not offer sufficient inducement for the construction of new vessels to take the place of the wartime-built ships that were gradually obsolescing and to compete with the more modern vessels of other nations that were being built from year to year. Congress recognized the importance of this situation and, to encourage the building of new vessels, passed the Merchant Marine Act of 1928, which contained two very important provisions for the upbuilding of the American merchant marine.

To compensate them for services in foreign trade, owners were awarded contracts under the provisions of this act to carry mails in foreign-trade routes for a period of 10 years, as an aid in overcoming the differential in operating costs between American and foreign ships and to encourage the construction of new tonnage. These ocean-mail contracts required the building of a certain minimum of new modern vessels or the thorough remodernizing of old ones.

To encourage the construction of ships, the act increased the Construction Loan Fund created by the act of 1920 and liberalized its provisions. The Shipping Board was allowed to lend money to owners for building purposes at low rates of interest up to three quarters of the cost of new construction.

Under the provisions of the act, 31 high-grade combination passenger and cargo vessels, as well as 9 tankers and 2 seatrain carriers, were con-

structed, forming a real nucleus of highly efficient vessels for our American merchant marine, although these vessels entered service at the depth of the world depression prevailing during much of the past decade.

The aids granted by the 1928 act, particularly the mail-contract provisions, were similar in character, though more liberal, than those provided by the Postal Aid Law of 1891 or the much earlier act of March 3, 1845, and were what is known as "indirect aids" rather than a direct subsidy for building and performance. There was much criticism of the 1928 act by certain members of Congress because of this fact and also because of a weakness in the act in that it did not encourage the construction of vessels of the cargo-carrying type. This criticism resulted in the passage by Congress of the Merchant Marine Act of 1936.

On June 10, 1933, by virtue of the authority granted him by the act of March 3, 1933, the President of the United States ordered that the functions of the Shipping Board be transferred to the Department of Commerce and that the United States Shipping Board be abolished. A Shipping Board Bureau in the Department of Commerce was organized to care for financial and policy merchant-marine affairs until the passage of the act in 1936, which provided for the creation of a Maritime Commission to carry out its provisions.

The Merchant Marine Act of 1936. The act of 1936 provides two distinct subsidies in aid of merchant shipping in foreign trade. The first is a subsidy under which the Government pays the difference between the cost of a vessel built in the United States and a vessel built abroad for similar service, so that the cost of new construction to the owner is the foreign cost as nearly as can be determined by the Maritime Commission. In addition, the Government can pay to ship operators under the act a subsidy sufficient to overcome the difference in the operating cost of an American vessel over the cost of operating a foreign vessel in the same or similar trade routes.

The act provides also for a cancellation of existing mail contracts with ship operators, for the adjustment of claims thereunder, and for new operating contracts. It also requires the Maritime Commission to determine what additions and replacements are required to carry out the national policies declared in the act, and it directs the commission to study, perfect, and adopt a long-range program for replacements and additions to the American merchant marine.

The act authorizes the Maritime Commission to build vessels on its own account for sale or charter to private owners and to encourage private owners to build for their own account under the provisions of the act.

In order to accomplish the purposes of the act, the Maritime Commission started a building program which, in conjunction with some vessels being built for private operators with Government aid, aggregated a total, as of June 1, 1941, of 705 commercial vessels of the passenger, combination, cargo, and oil-tanker types. This program has been advanced because of the national emergency existing. The U. S. Maritime Commission's regular program does not include a large number of standard type cargo vessels (known as the Liberty Fleet) now under construction

for aid to Great Britain. The general characteristics of some of the types of vessels building under this program are as follows:

TABLE II

MEASUREMENT, TONNAGE, SPEED, AND PASSENGER CAPACITY OF DIFFERENT TYPES OF VESSELS

Type of Vessel	*Length Over-All in Feet*	*Breadth in Feet*	*Depth Molded in Feet*	*Tonnage in Gross Tons*	*Speed in Knots*	*Number of Passengers Accommodated*
America, passenger vessel . .	723	93′ 3″	45′ 4½″	25,000	22	1,219
C-3, cargo and passenger vessel						
Steam	492	69′ 6″	42′ 6″	9,300	16½	96
Diesel	492	69′ 6″	42′ 6″	8,030	16½	60
C-3, cargo vessel	492	69	42′ 6″	7,676	16½	
C-2, cargo vessel	459	63	40′ 6″	6,085	15½	
C-1, cargo vessel	416	60	37′ 6″	6,750	14	
Oil tanker . .	553	75	39	11,300	18½	

The construction program of the Maritime Commission at this time creating a fleet of up-to-date commercial vessels—mostly of the cargo type, which are badly needed—should place the United States, at the end of the present war, in a good position to carry on and to hold its important export and import trade.

Effect of registry laws upon shipping. Prior to the passage of the Panama Canal Act of August 24, 1912, and of the Ship Registry Act of 1914, no foreign-built vessel, unless wrecked on the shores of the United States and repaired in this country, at a cost of not less than three times the salvaged value of the vessel, captured in war, or forfeited for breach of our laws, could be registered under the American flag and engage in either our foreign or coastwise trade.

There has never been any restriction against a vessel built abroad and owned by an American citizen operating under a foreign flag either in American foreign trade or in any other foreign trade. Probably with this thought in mind, Congress, in enacting the Panama Canal Act of 1912, which is still in force, included a provision permitting any foreign-built merchant vessel not over 5 years old to be placed under American registry, to fly the American flag, and to engage in our foreign trade. Under a provision of the act of 1914, the 5-year limitation was stricken out, and now any foreign-built vessel, regardless of age, can be placed under the American flag and operated in foreign trade.

As a war measure, in 1917, Congress opened our coastwise trade to foreign-built vessels, but closed it again in 1920. Under the Merchant Marine Act of 1920, however, all foreign-built vessels admitted to American registry and owned on February 1, 1920, by citizens of the United States may engage in the coastwise trade as long as they continue such

ownership, subject to the rules and regulations of such trade. This legislation had a serious effect on the shipbuilding industry, as it provided for admission to the coastwise trade for operation throughout their lifetime of approximately 970,000 tons of foreign-built vessels.

With these exceptions, however, foreign-built vessels are, under the act of 1817, still prohibited from engaging in our coastwise trade.

The Merchant Fleet of the United States

Shipping (1940). The merchant fleet of the United States consists of vessels engaged in foreign, coastwise, Great Lakes, and river trades. Coastwise shipping includes both coastal and intercoastal shipping. In addition to large vessels for seagoing and Great Lakes services, there are also large numbers of miscellaneous craft, such as tugs, barges, lighters, carfloats, and other types in the merchant marine.

The total tonnage of merchant vessels, each of 100 gross tons or over, in the seagoing and Great Lakes services, together with idle tonnage under the American flag, as of July 1, 1939, was 11,874,384 tons.

Of the larger vessels which constitute the major part of the seagoing merchant marine (excluding the Great Lakes), each of 1,000 gross tons or over, there were a total of 1,192 vessels of 7,051,298 gross tons under the American flag as of March 31, 1941, of which 68 vessels of 326,230 tons were idle at that time. Of the active fleet, 415 vessels of 2,576,884 gross tons were in the foreign trade and 706 vessels of 4,115,048 gross tons in the coastwise trade. Included in American shipping is the American oil-tanker fleet of approximately 365 vessels of 2,634,393 gross tons, representing about one fourth of the world's tanker tonnage. Seagoing vessels of all types are important as a factor in national defense. The tanker fleet is a necessary adjunct to our fleet of both Government and commercial vessels, as it is necessary to supply huge quantities of liquid fuel in constant volume to customers.

The motive power of American seagoing vessels is of several types, such as reciprocating engines, steam turbines, Diesel engines, electrical propulsion, and combinations of the above types. Reports of shipbuilding during the past few years indicate a gradually increasing percentage of tonnage of ships fitted with Diesel engines, the actual percentage being higher abroad than in the United States. The world tonnage of seagoing vessels (100 tons and over) under construction on July 1, 1939, was about as follows:

	Number of Vessels	*Tonnage in Gross Tons*
Steamers.............	290	1,221,612
Motor ships	410	1,624,707

Great Lakes shipping. Vessels under the American flag in service on the Great Lakes as of April 1, 1940 numbered 447 vessels, aggregating 2.373,911 gross tons. Of these, all but 13 are fitted with reciprocating engines, while 4 that were recently built are fitted with steam turbines.

These vessels are largely for the carriage of iron ore, coal, grain, and other bulk commodities. Some of them exceed 600 feet in length and can carry over 13,000 tons of cargo. The entrance of vessels from the ocean to the Great Lakes, or passage from the Great Lakes to the ocean, is controlled by the size of the canal locks through which such vessels have to pass. The limit in size at the present is for vessels with an over-all length of 261 feet, a beam of 43 feet, 6 inches, and a draft of about 13 feet.

Trade on the Great Lakes between United States ports is domestic, and that between ports of the United States and Canada is foreign. Great Lakes trade is seasonal, opening in March or April and continuing until ice forms on the upper lakes in November or December. It is estimated that the total water-borne domestic trade on the Great Lakes in 1938 was 82,500,000 short tons, valued at about $1,338,000,000, and the trade with Canada was about 15,820,000 short tons, valued at about $176,160,000.

River shipping. With the development of the West, river shipping, particularly on the Mississippi and Ohio Rivers, increased rapidly In the early days, the great bulk of trade moved downstream. Barges—including flatboats, arks, broadhorns, and other nonpropelled vessels—floated downstream with the current, using side sweeps with a long oar in the stern for steering. The flatboat was the type most extensively used. It was about 40 feet long and was handled by oars. At the end of the journey, the flatboats were broken up and sold for lumber.

Notwithstanding the general use of the flatboat, it was reported that, in 1808, there were about 25 or 30 barges in operation, making usually one round trip per year on the Mississippi River. These barges carried from 40 to 100 tons of freight, descended with the current, and were worked upstream by various devices, such as oars, poles, tow ropes, sails, animal towage, and other methods. The cargo carried on the return trip consisted of only a few barrels of coffee or, at most, 100 hogsheads of sugar. The trip downstream, from Pittsburgh to New Orleans, was accomplished in about 1 month, whereas the trip upstream took from two to three times as long. In the year 1811, it was estimated that there were more than 300 keelboats (boats propelled by push poles) on the Ohio River and its tributaries. These boats were pointed at bow and stern, were from 12 to 15 feet in width and about 50 feet long, and carried from 20 to 40 tons of freight, well protected from the weather. The crew consisted of from 6 to 10 men besides the captain.

It is reported that one steamer, in the year 1816, passed no less than 2,000 miscellaneous floating craft other than steamers on its trip from Natchez to Louisville.

The number of steamers on the Western rivers increased rapidly from 1820. It is estimated that, in the year 1855, there were 750 steamers afloat on these rivers. The construction of railroads throughout the West from 1840 to 1860 caused a decline in the development of shipping on the Western rivers. At this time, a number of railroads were in competition with each other, and freight rates were cut indiscriminately. The railroad competition became so severe that, in the year 1877, the

principal trunk-line carriers entered into an agreement fixing freight rates to the Atlantic ports. The stabilization of rates again encouraged traffic on the Mississippi.

The use of steam-packet boats on the Ohio and Mississippi was at its height just preceding the Civil War. Packet boats were driven either by stern or by side wheels. In the seventies and eighties, boats having a length of about 200 feet were frequently built for river service.

On the Ohio River, traffic in coal, which was the major towing operation, was in its infancy in 1850 and reached its height from 1880 to 1905. Coal was towed in barges, and records of 1882 show that these tows below Louisville frequently carried as much as 25,000 tons.

Barges are now generally constructed of steel and are from 800 to 1,000 tons capacity. Covered barges are used for transporting steel, cement, and miscellaneous freight. Specially constructed tank barges are used for the carriage of oil and gasoline.

The deepening of channels and other improvements to the inland waterways have greatly increased the opportunities for inland-waterway transportation, so that, in recent years, great numbers of barges and other river craft have been built. It is estimated that, in the year 1938, the total water-borne commerce on the rivers, canals, and connecting channels aggregated about 277,755,000 short tons and was valued at about $5,657,887,000.

Modern Vessels

Types, size, and speed. Present-day seagoing vessels of large size are constructed of steel and are self-propelled by steam reciprocating engines, turbines, internal-combustion engines (commonly known as "Diesels"), or by a combination of steam and electric or Diesel and electric power. Until 1900, about one half of the tonnage of the United States merchant fleet was still operated by sail power. It is interesting to note the increase in the size of vessels during the past 25 years. In 1914, there were around 24,400 steam and motor ships in the world, approximating 45,400,000 gross tons. In 1939, this number had increased to 29,800 ships, with a tonnage of almost 68,500,000 gross tons, showing that the average size of ships had increased from about 2,000 gross tons each in 1914 to about 2,500 tons each in 1939.

Owing to the use of oil instead of coal in steam installations and to a greater use of Diesel machinery, the demand for oil has increased to such an extent that the world fleet of oil tankers at the present time is upward of 12,000,000 gross tons, as compared with 1,500,000 in 1914.

Present-day construction of wooden vessels for seagoing commercial purposes is very rare. While many small ships of wood were built during the First World War period, only a few were ever used, and all have since been converted into barges or have been scrapped. Although the wood sailing vessel first established American maritime power, it is only in the field of racing that our sail craft make modern records. We have consistently captured the greatest of yachting prizes since 1857, the

America cup. The oceans and lakes are evidence that, for pleasure, the wooden sailboat is still much with us. On smaller inland waters, powerboats—more than 200,000, some of wood and some of metal—take precedence in numbers over sailboats. Together they keep America interested and enthusiastic about her seas and rivers and lakes.

The trend in the construction of passenger vessels has continued in recent years toward greater size, higher speed, and more comfort. The first outstanding modern vessels of great size, the *Mauretania* and the *Lusitania*, over 750 feet long and capable of a speed of 25 knots, were built in England in 1907. These were followed, before the First World War, by German and other British vessels and, after the war, by the *Bremen* and *Europa*, built in Germany and placed in operation in 1932, later by the *Rex* and *Conte di Savoia*, built in Italy, and still later by the *Queen Mary* and *Queen Elizabeth*, built in Great Britain, and the *Normandie*, built in France. Some of these later vessels exceed 1,000 feet in length. The three largest are the *Queen Elizabeth*, of 85,000 gross tons, 1,031 feet in length, and with a beam of 118 feet; the *Normandie*, of 83,423 gross tons, 1,029 feet, 4 inches in length, 36 feet, 7 inches in depth, and with a beam of 117 feet, 9 inches; and the *Queen Mary*, of 81,235 gross tons, 1,019 feet, 6 inches in length, 38 feet, 9 inches in depth, and with a beam of 118 feet. The greatest speed of the *Queen Mary* eastbound was 31.69 knots in August, 1938, and westbound in the same month 30.99, with the highest day's run 738 miles, averaging 32.07 knots. This is somewhat in excess of the highest run recorded by the *Normandie*. The average Annual Conference Speed in 1938 was 29.11 knots for the *Queen Mary* and 28.77 for the *Normandie*. While the latest of the large vessels, the *Queen Elizabeth*, has made a western crossing of the Atlantic, at this writing, she is not yet engaged in regular transatlantic service.

The largest commercial passenger vessel to be built in the United States is the *America*. It is of 24,800 gross tons, 723 feet in length, 93 feet, 3 inches beam, and 45 feet 4½ inches depth, and is designed for an average sea speed of not less than 22 knots. This vessel was completed in June, 1940.

The trend in cargo-vessel construction is toward higher speeds, better ship forms, higher efficiency of machinery, and added comfort for officers and crew. The average speed of cargo vessels before and during the First World War period was from 10½ to 11½ knots, while the speed of cargo vessels recently built or now being built ranges, in general, from 15½ to 16½ knots. As the speed increases, the cost naturally increases because of heavier and more powerful machinery.

In both passenger and cargo vessels of recent design, great attention has been given to increased safety, not only in the subdivision of the ship so as to make it as nearly unsinkable as possible, but in protection against fires and in better navigating equipment, in improved wireless apparatus enabling a ship in distress to communicate its location quickly to other ships on the sea, and finally, in the event of a catastrophe, in more and better means for abandoning the ship.

Welding. The introduction of welding has brought about great changes in the methods of ship construction. The decade from 1930 to 1940 has witnessed marine welding, first in its experimental stage, and then in its gradual extension to barges and seagoing ships of smaller size, until in 1940, ships of upward of 500 feet in length are being completely welded. Welding has brought about a reduction in weight of the ship itself, which is another factor in cheapening the cost of operation; and it is anticipated that, with more experience, welding will ultimately decrease the labor cost of construction.

On June 30, 1939, about 57 per cent of the gross tonnage of vessels under construction were those to be driven by internal-combustion engines, known as "motor ships," and 43 per cent to be driven, directly or indirectly, by steam propulsion, termed "steamships."

Shipbuilding as a National Utility

National need of shipbuilding and ship-repair yards. The shipyards of the United States are a national asset, and in order to be available in a time of national emergency, they must be kept in efficient operation at all times for the construction of both merchant and naval vessels. Their necessity was confirmed by the lack of shipbuilding facilities during the war of 1914 to 1918, first while the United States was a neutral, and more emphatically after the United States had become a belligerent. It is a lesson which America should never forget. During that period, it became necessary for the United States to inaugurate its great emergency shipbuilding program for the construction of both merchant and naval vessels under abnormal and expensive conditions. Since the First World War and up to a year ago Government navy yards have constructed about one half of all United States naval vessels. Under the present emergency, however, private shipbuilding industry has been called upon to build about 80 per cent of the naval vessels now under construction.

Shipbuilding is a highly specialized industry, and its nature is such that it requires the maintenance of a large staff of technical employees for the preparation of ship designs, who must keep abreast of the art and science of shipbuilding not only in the United States but throughout the world. The mechanical trades must also be composed of men of experience and training in shipbuilding practices, and it is possible to have shipbuilders and a shipbuilding industry in readiness in time of need only by keeping the industry in an efficient operating condition at all times. At the end of the first quarter of 1941, there were about 100,000 men employed in the private shipyards and ship-repair plants of the United States on new construction and repair work, and at least an equal number in allied industries producing shipbuilding material and equipment. Taking into account the building and repairing of naval vessels in Government navy yards, together with those in the private shipbuilding industry and in the allied industries, there are, at the present time, approximately 400,000 people employed in private shipyards, Government navy yards, and allied marine industries. In the shipyard, where the fabrica-

tion of a vessel is carried on, there are at least 24 mechanical trades requiring skilled labor in large volume. Many more trades are employed in smaller numbers and, in addition, much unskilled labor is required.

Although war again holds the stage in Europe, American shipyards are not in the unfortunate position they were in 1914 but, staffed with highly efficient organizations, are actively engaged in a large building program for both the Navy and the merchant marine.

Shipyards for building seagoing vessels must be located adjacent to deep water and usually exist, therefore, at or near principal shipping ports, the 10 most important of which in 1940, in the order of the value of goods passing through them were: New York, Detroit, New Orleans, Buffalo, Baltimore, Philadelphia, Galveston, Los Angeles, San Francisco, and Boston.

There are 89 private shipyards in the United States now engaged in the building of naval and seagoing commercial vessels, 46 on the Atlantic Coast, 11 on the Gulf Coast, 21 on the Pacific Coast, and 11 on the Great Lakes. Seventy of the shipbuilding companies are engaged in the building of naval vessels. There are 8 Government navy yards in the United States—6 on the Atlantic Coast and 2 on the Pacific Coast—engaged at the present time in the building of naval vessels.

According to a recent survey by the National Council of American Shipbuilders, there are 286 active shipbuilding ways in the United States, each of 300 feet or more in length, suitable for building seagoing vessels and 12 other ways that can be made quickly available for that purpose. In addition, there are ample building ways on the Great Lakes and the great rivers to meet the demands for ships on those waterways. The map of the United States herein reproduced shows those states on the seaboard, on the Great Lakes, and on the great rivers that have active shipyards. It is interesting to note that states having shipbuilding facilities contain 88 per cent of the population and 57 per cent of the area of the country.

All of the principal ports in which merchant vessels enter and clear have ship-repair yards adequate to repair and recondition merchant vessels. It is, of course, essential that these repair facilities be readily available near the port where vessels discharge or load cargo, so that repairs may be quickly made and avoid delay in sailing schedules.

Entirely aside from its value as a national utility, shipbuilding is an important industry which gives employment directly and indirectly to large numbers of people well distributed throughout the United States. Among the industries supplying shipbuilding material and equipment are those making steel, propelling machinery, electrical apparatus, Diesel engines, boilers, auxiliary and deck machinery, pumps, lifeboats and their equipment, copper and brass products, iron and steel castings, galley and pantry equipment, fire-fighting equipment, plumbing fixtures, navigating instruments, heating units, interior decorations, furniture, woodwork, special paints and varnishes, canvas and deck coverings, safety devices, and radio and other instruments; and each one of the industries supplying such

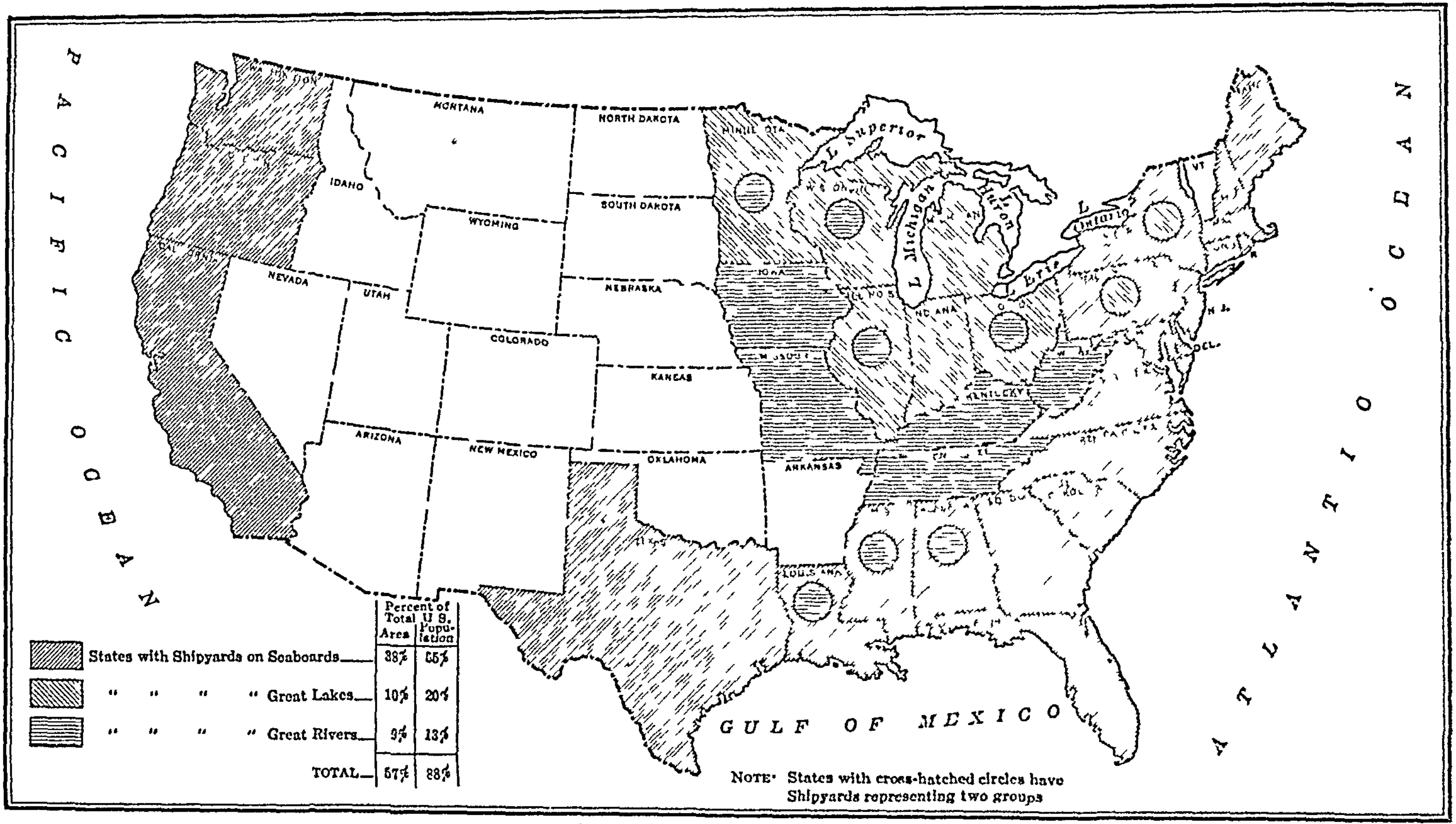


Fig. 1. Shipbuilding states

commodities makes a demand on other industries for the products they use in the manufacture of materials and equipment.

In building the large passenger liner *America,* at least 275 business organizations in the United States received orders for material and supplies entering into its construction. Transportation charges on materials used in ship construction are estimated to amount to from 4½ to 5 per cent of the ship's cost.

The accompanying chart shows the value and approximate distribution of the shipbuilding materials and equipment used in a $75,000,000 program for the construction of new merchant vessels of numerous types. (The figures can be expanded or reduced to fit any given program.)

Manning of the vessels documented in the United States requires the service, at the present time, of approximately 200,000 men, of whom some 23,000 are employed on vessels engaged in foreign trade, excluding longshoremen, warehousemen, dockmen, Government employees, and others directly connected with marine personnel. It is estimated that our waterborne foreign commerce gives employment to 250,000 wage earners.

Modern Shipbuilding

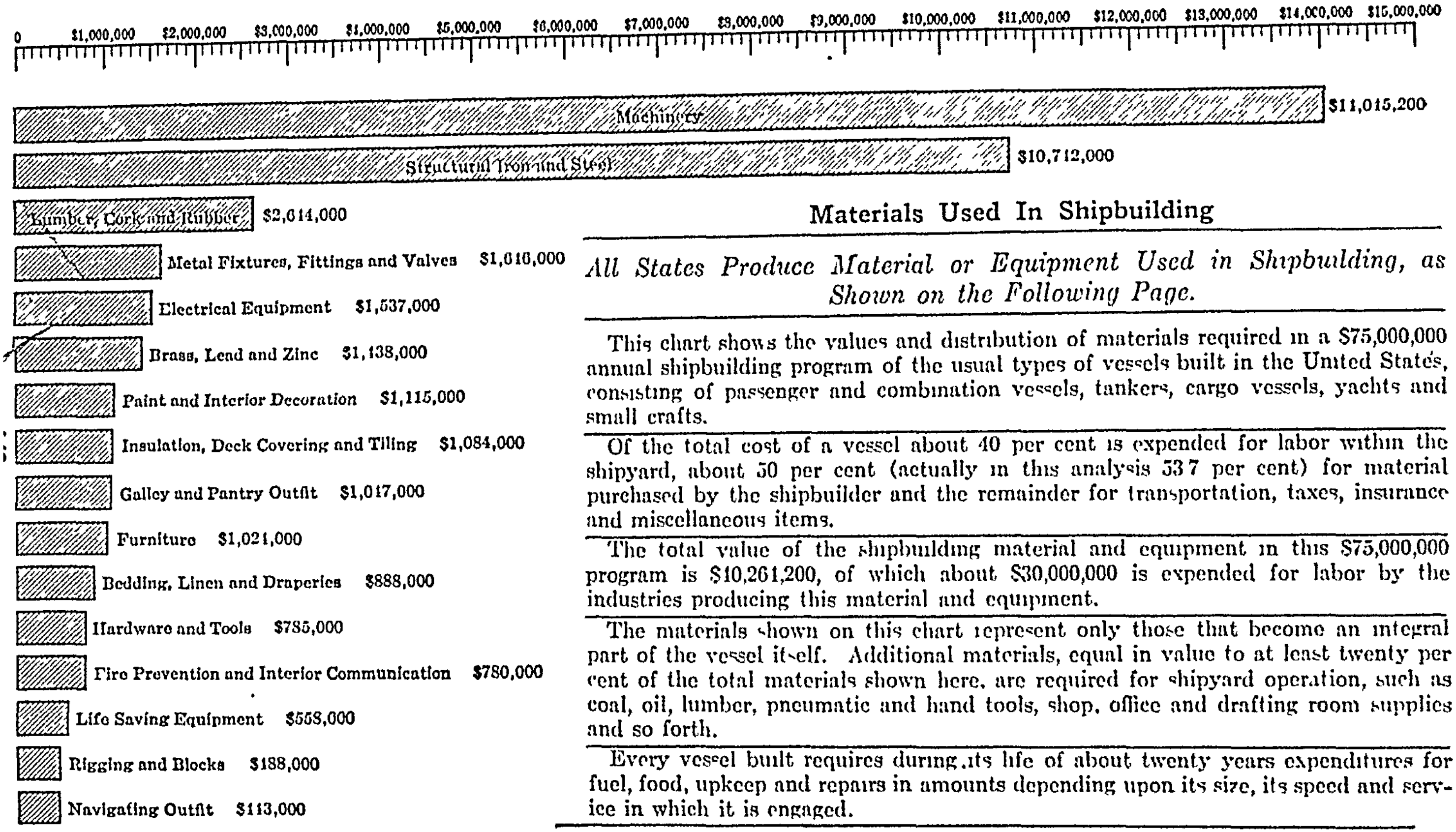
Operation of a modern shipyard. The first step in building a ship is the preparation of designs, which requires a staff of experienced naval architects, engineers, and draftsmen. When the designs are sufficiently advanced, schedules for ordering and delivering the materials are prepared and the materials are ordered. The building ways on which the vessel is to be constructed are now made ready.

Steel material is needed first in the construction of a vessel for its frames, beams, and plating. From the designs, which are developed in the drafting room, full-size wood or paper patterns are made of the various pieces of the ship's structure. The steel parts are shaped to fit these patterns.

When the steel parts are completed in the shops, they are assembled on the ship in readiness for riveting or welding. Welding instead of riveting, as now extensively used in building vessels of all types, has resulted in the elimination of much heavy shop machinery, as well as air-compressor and pneumatic-tool equipment.

Patterns are made from machinery designs for the necessary castings. These, along with forgings and other miscellaneous purchased material, are ordered, and the building of machinery begins upon their receipt.

When the ship's steel structure is sufficiently advanced, the installation of special supports, auxiliary machinery, piping systems, electrical wiring and accessories, insulation, lighting, and ventilation is begun. Modern vessels have very little woodwork, partitions between rooms being either of steel or noncombustible material. When the structural work is advanced nearly to completion, the vessel is launched, whereupon the main propelling machinery and other heavy weights are put aboard and fitted into place. Furniture, equipment, and outfit are then placed on board, and interior painting and decoration are finished, then, when the machin-



Materials Used In Shipbuilding

All States Produce Material or Equipment Used in Shipbuilding, as Shown on the Following Page.

This chart shows the values and distribution of materials required in a $75,000,000 annual shipbuilding program of the usual types of vessels built in the United States, consisting of passenger and combination vessels, tankers, cargo vessels, yachts and small crafts.

Of the total cost of a vessel about 40 per cent is expended for labor within the shipyard, about 50 per cent (actually in this analysis 53.7 per cent) for material purchased by the shipbuilder and the remainder for transportation, taxes, insurance and miscellaneous items.

The total value of the shipbuilding material and equipment in this $75,000,000 program is $10,261,200, of which about $30,000,000 is expended for labor by the industries producing this material and equipment.

The materials shown on this chart represent only those that become an integral part of the vessel itself. Additional materials, equal in value to at least twenty per cent of the total materials shown here, are required for shipyard operation, such as coal, oil, lumber, pneumatic and hand tools, shop, office and drafting room supplies and so forth.

Every vessel built requires during its life of about twenty years expenditures for fuel, food, upkeep and repairs in amounts depending upon its size, its speed and service in which it is engaged.

Fig. 2.

Alabama
- Iron ore
- Limestone
- Coal
- Coke
- Pig iron
- Steel
- Cotton
- Yellow pine
- Iron castings
- Machinery
- Anchors
- Clay products

Arizona
- *Copper ore*
- Silver
- Lead
- Zinc
- Leather
- Wool

Arkansas
- Ash lumber
- Yellow pine
- Cotton
- Petroleum
- Bauxite

California
- Steel
- Machinery
- Hard and soft woods
- Petroleum
- Red lead
- Insulating paper
- Glassware
- Asbestos
- Wool
- Cement

Colorado
- Copper ore
- Lead
- Silver
- Zinc
- Wool

Connecticut
- Hardware
- Cutlery
- Silverware
- Chain
- Pipe fittings
- Clocks and gauges
- Brass products
- Lighting fixtures
- Tools

Delaware
- Steel

Florida
- Lumber
- Naval stores
- Veneers

Georgia
- Cotton
- Yellow pine
- Turpentine
- Canvas

Idaho
- Lead
- Silver
- Zinc
- Manganese
- Lumber

Illinois
- Iron ore
- Limestone
- Coal
- Coke
- Petroleum products
- Hardware
- Valves
- Paints

Indiana
- Limestone
- Coal
- Cement
- Oak lumber
- Alcohol
- Pumps
- Electric motors

Iowa
- Coal
- Clay products
- Firebrick
- Cement
- Gypsum
- Furniture

Kansas
- Zinc
- Petroleum
- Leather
- Glass products

Kentucky
- Hardwoods
- Coal
- Petroleum
- Firebrick
- Leather
- Hemp

Louisiana
- Yellow pine
- Cypress
- Oak
- Cotton
- *Petroleum*
- Rope
- Gum

Maine
- *Lumber*
- Clay products
- Wood pulp
- Paper
- Winches
- Windlasses
- Steering gears

Maryland
- Coal
- Iron rails and pipe
- Steel plates
- Steel wire
- Brass and copper tubes and sheet
- Oakum
- Canvas
- Tin plate

Massachusetts
- Turbines
- Electrical machinery
- Plumbing fixtures
- *Leather belting*
- Rugs and draperies
- Manila rope
- Navigating instruments
- Insulating paper

Michigan
- Iron ore
- Limestone
- Cement
- Copper products
- White pine
- Plywood
- Hardware
- Tools
- Furniture
- Paints

Minnesota
- Iron ore
- *Pig iron*
- Clay products
- White pine
- Flax
- Linseed

Mississippi
- Cotton
- Yellow pine
- Veneers

Missouri
- Machinery
- Lead
- Zinc
- Cement

Montana
- Copper ore
- *Zinc*
- Silver
- Manganese
- Wool
- Lumber
- Leather

Nebraska
- Clay products
- Cement
- Leather
- Wool

Nevada
- Copper
- Silver
- Gypsum
- Lead
- Zinc
- Manganese
- Silica
- Wool

New Hampshire
- Clay products
- Mica
- Silica
- Ebony
- Asbestos
- Machinery

New Jersey
- Manufactures
- Machinery
- Galley equipment
- Fans, pumps, etc.
- Glass
- Paints
- Varnishes
- Furniture
- Textiles

New Mexico
- Copper ore
- *Zinc*
- Petroleum
- Wool
- Mica

New York
- Machinery
- Manufactures
- Textiles
- Wood pulp
- Rope
- Telephones
- Electrical apparatus
- Glassware
- Cork
- Asbestos

North Carolina
- Cotton goods
- Canvas
- Lumber
- Copper
- Aluminum
- Mica
- Furniture
- Veneers

North Dakota
- Clay products
- Coal
- Wool
- Hemp
- Linseed

Ohio
- Iron pipe
- Steel products
- Limestone
- Rubber
- Machinery
- Paints
- Varnishes
- Anchors and chain
- Hardware and tools
- Heaters
- Evaporators

Oklahoma
- Cotton
- Lead
- Zinc
- Fuel oil
- Lubricants

Oregon
- Oregon pine
- Spruce
- Cedar
- Machinery
- Copper wire
- Cement

Pennsylvania
- Coal
- Steel products
- Cement
- Glass products
- Manufactures
- Hardware
- Tools
- Machinery
- Refrigerating apparatus
- Paints

Rhode Island
- Clay products
- Lime
- Graphite
- Textiles
- Machinery
- Hand tools

South Carolina
- Cotton products
- Naval stores
- Lumber
- Canvas

South Dakota
- Cement
- Wool
- Hemp
- Linseed

Tennessee
- Coal
- Iron ore
- Lumber
- Machinery
- Cotton

Texas
- *Cotton*
- Wool
- Petroleum products
- Southern pine
- Ash lumber

Utah
- Copper ore
- Silver
- Lead
- Zinc
- Wool

Vermont
- Machinery
- Lumber
- Marble
- Lime
- Asbestos
- Plywood
- Paints
- Tools
- Steel wire

Virginia
- Coal
- *Iron ore*
- Sheet aluminum
- Emery
- Mica
- Machinery
- Office supplies

Washington
- Oregon pine
- *Cedar*
- Spruce
- Cement
- Machinery
- Wire rope
- Veneers

West Virginia
- Coke
- Coal
- Oils
- Porcelains
- Steel castings
- Lumber

Wisconsin
- Iron ore
- Zinc
- White pine
- Wood pulp
- Plywood
- Machinery

Wyoming
- Iron ore
- Fuel oil
- Wool

Fig. 3. Materials or Equipment Furnished for Shipbuilding by the Various States.

ery installation is completed, the vessel is given a machinery trial alongside dock, and later a trial trip is conducted at sea to test the efficiency of the machinery and seaworthiness of the ship. After satisfactory trials and any post-trial adjustments, the vessel is ready for delivery.

During all stages of construction, the materials and the work itself are inspected by the owner and representatives of the classification society and also by representatives of the various Government bureaus concerned to assure that the rules and regulations prescribed by law for the building of vessels are carried out.

Every conceivable method to increase shipyard efficiency has been studied, and those judged sound have been adopted, often at great expense. In the field of research, continued important results have been developed from many sources, outstanding among which are model-tank tests. At the present time, the largest and most up-to-date model tank in the world for testing ship models and propellers is in operation at Carderock, Maryland.

Shipyard organizations for the conduct of work with expedition and economy are worked out in great detail, particularly in those shipyards building vessels of the larger size. Plans, complete in every detail, showing the work to be performed are prepared. In the smaller shipyards, devoted wholly to the building of vessels of small size, the organizations are less complicated, much being left to the judgment of foremen and mechanics directly employed on the work.

Some shipyards build their own machinery; others purchase it from industries specializing in machinery building. Because of the great variety of work involved in the building of a vessel, an adequate shipyard layout necessitates buildings covering a large area, outfitted with many kinds of machinery, cranes, hoists, and other handling facilities. In addition, the shipyard must have one or more wet slips, or berthing spaces, with water of sufficient depth to permit a vessel, after launching, to lie alongside the dock and to be kept free from grounding.

Financing ship construction. In the construction of merchant vessels for a private owner, when financial relations with the Government are not involved, the matter of financing the undertaking is entirely between owner and builder, the owner making payments as the work proceeds, in compliance with the terms of the contract.

Under contracts in which the Government aids in the construction of vessels, under the provisions of the Merchant Marine Act of 1936, the Government pays the difference between the cost of building the vessel in an American shipyard and the estimated cost of building a vessel of the same design in a foreign shipyard, and the owner finances at the time of building not less than 25 per cent of the price he pays for the vessel (foreign cost) and pays off the balance, with interest, in 20 annual installments. The Government's security in the vessel is a first mortgage upon it. Vessels constructed with Government aid are required to be built so that they may be readily converted into naval or military auxiliaries. To accomplish this purpose, the plans and specifications are submitted by the Maritime Commission to the Secretary of the Navy for his approval.

Classification, inspection, admeasurement, and registration. As a guaranty that vessels are strongly and correctly built and as an aid to securing the minimum rate of insurance upon the cargo they are carrying, it is obligatory, where vessels are built with Government aid, that they should comply with the rules of the American Bureau of Shipping, a classification society. Ships built by private owners are also usually classified. There are several classification societies, among which, in addition to the American Bureau of Shipping, is the British Lloyd's Register of Shipping, the French Bureau Véritas, and others. Nearly every maritime country has a classification bureau of its own, and any one of them will generally classify the vessel of another nation if so desired. These societies are well versed in the practices of ship construction and not only issue rules for the construction of hulls and machinery, together with requirements for certain periodic surveys to insure that ships are properly maintained to retain their assigned classifications, but also publish registers giving particulars of vessels and their classification.

The American Bureau of Shipping has its headquarters in New York City. This classification society is a nonprofit organization, with representatives of shipowners, underwriters, and shipbuilders on its board of managers. To carry out the work of the society, which emphasizes the testing of material and the supervision of hull and machinery construction, the bureau maintains a competent staff of surveyors in all the principal ports, both at home and abroad.

It should be understood that classification of a vessel is entirely optional on the part of a shipowner. Some vessels are built without classification, but this is usually in cases where an owner carries his own insurance and assumes all risks.

As a requirement that vessels shall not be overloaded, the Congress of the United States, in 1929, enacted the United States Load Line Law for vessels engaged in foreign trade by sea. This law became effective on September 2, 1930, and while its enforcement is under the jurisdiction of the Secretary of Commerce, he has appointed the American Bureau of Shipping to determine whether the position and manner of marking the load line or lines on vessels are in accordance with the act and the regulations established thereunder.

Inspection. As a guaranty for the safeguard of passengers and crew, vessels must be built to conform to the general rules and regulations prescribed by the Bureau of Marine Inspection and Navigation, Department of Commerce. This service issues licenses to personnel, prescribes the numbers of officers and crew a vessel shall carry, the requirements for bulkheading, marine boilers, lifesaving equipment, fire-fighting equipment, and some other items, and inspects materials and vessels during the building to see that they conform to these requirements. Vessels are also inspected periodically after they are built to see that lifesaving equipment and boilers are kept in satisfactory condition for safe operation.

America's safety record in water-borne passenger travel stands unchallenged in the 10 years from 1924 to 1933, inclusive. The Bureau of Marine Inspection and Navigation reports that, during the above-

mentioned period, on vessels required by law to report the number of passengers carried, only 1 passenger was lost for every 10,668,118 carried, and that in the 10-year period from 1930 to 1939, inclusive, only 1 passenger was lost for every 9,391,021 carried. During the period subsequent to the passing of the new maritime legislation—that is, from June, 1935, to June, 1940 (estimated number of passengers carried in 1940, 200,000,000)—but 1 passenger life has been lost due to casualty, while the merchant vessels of the United States during this period have carried 1,307,505,424 passengers.

All commercial vessels are subject to other inspections from the drafting board to final delivery. The Maritime Commission, the Navy Department, the Public Health Service, the Department of Commerce, the classification bureaus, the owner, and other organizations pass on design and inspect ships during building. These precautionary measures add greatly to cost before delivery but insure adherence to specifications and the genuine quality of all components.

Admeasurement. As a prerequisite to documentation (register, enrollment, or license), vessels are admeasured to determine their gross and net tonnages, one of which may be the basis for the collection of port dues, pilotage, dockage, canal tolls, navigation fees, and so forth. Upon a ship's tonnage is also based the amount of certain lifesaving equipment. In addition, crew spaces are measured to determine the number of men that may be berthed therein. Admeasurement is under the jurisdiction of the Bureau of Marine Inspection and Navigation, in the Department of Commerce, and a vessel's net tonnage (in tons of 100 cubic feet each) is required to be marked in a prescribed location on the vessel.

Documentation. There is no affirmative statutory requirement that vessels built in and owned by citizens of the United States be documented as vessels of the United States. However, under this country's navigation laws, for vessels to be entitled to the rights and privileges of United States vessels, and to engage in foreign and domestic commerce, it is necessary that they be documented as vessels of the United States.

The documents which are issued to vessels are of five forms: register, enrollment and license, license, enrollment and yacht licenses, and yacht license. A registered vessel may engage in trade with foreign countries, in the coastwise trade, and also in the whale fisheries. An enrollment and license permits a vessel of 20 tons and over to engage in the business stated thereon, which may be either the coasting trade, mackerel fishery, cod fishery, or coasting trade and mackerel fishery. A license permits a vessel of less than 20 tons to engage in the business stated thereon, which may be either the coasting trade, mackerel fishery, cod fishery, or coasting trade and mackerel fishery. An enrollment and yacht license authorizes a vessel of 20 tons and over, used exclusively for pleasure, to proceed from port to port in the United States and to foreign ports without entering or clearing at the customhouse.

Yachts or boats used exclusively for pleasure of 16 gross tons or over may be documented. Yachts of 5 net tons or over and less than 16 gross tons may, if the owner so desires, be registered prior to visiting a foreign

country, and any yacht to which such register has been issued becomes subject immediately to all fees required of any other registered vessel. Vessels which are not used exclusively for pleasure and which are of 5 net tons or over must be documented.

Those vessels which are required by statute to be annually inspected must produce a valid certificate of inspection as a condition precedent to documentation.

No vessel having at any time acquired the lawful right to engage in the coastwise trade, either by virtue of having been built in or documented under the laws of the United States, and later sold foreign in whole or in part, or placed under foreign registry, can be redocumented as a vessel of the United States to engage in the coastwise trade. These vessels, together with foreign-built vessels, can only be documented to engage in trade with foreign countries or with the Philippine Islands and the Islands of Guam, Tutuila, Midway, Wake, and Kingman Reef.

Insurance of vessels. During the construction of a vessel, the builder carries what is known as "builder's risk insurance," and after the vessel is delivered, the owner carries the insurance on the vessel during its lifetime. As the amount of insurance on a vessel is large, it is generally carried by several companies and reinsured by them with other companies, so that, if a loss occurs, it is distributed and too great a burden is not imposed on any individual insurance company.

Capital investment in the shipping industry. There are no authentic figures as to the capital invested in the shipping industry of the United States. It is a large amount, as evidenced by the fact that a sum of about $3,000,000,000 was expended for merchant vessels during the First World War, although prices, because of the war, were abnormally high. Existing ships vary in age and depreciate yearly, and they are distributed over so many companies that accurate information as to their value is very difficult to obtain. The same is true as regards investment in the shipbuilding and ship-repairing industries.

An enormous investment is also represented by the docks, piers, warehouses, handling facilities, and railroad terminals, as well as by the work of dredging channels and constructing and maintaining lighthouses, lightships, and the many other items incident to and required for the safe, expeditious, and economical operation of shipping.

Future of the Industry

The future of the shipping industry in the United States depends upon the country's needs for trade, both domestic and foreign, and also upon the needs for shipping as naval and other Government auxiliaries. The coastwise trade, both coastal and intercoastal, is restricted to American-built vessels and is a domestic problem. It is, of course, in competition with railroads, motor trucks, motor buses, air lines, and pipe lines; but, for long hauls, it is cheaper than these other means of transportation. The importance of coastwise shipping insures its maintenance in substantial volume, with the assurance of replacement as vessels become ob-

solescent. The continuance of American shipping in foreign trade requires the continuance of Government aid as long as prevailing wage rates in the United States are higher than those abroad. The European war now under way has reëmphasized the importance of American ships in our foreign trade if the foreign markets for our products are to be reached in a time of emergency.

The preamble to our Merchant Marine Act of 1936 reaffirms in general the policy declared in the acts of 1916, 1920, and 1928, namely, that the United States should have a merchant marine sufficient to carry its domestic and foreign water-borne commerce in American-built ships. At the present time, 1941, the percentage of American goods in foreign trade carried in American vessels is about 25 per cent by volume.

The people of the United States now generally recognize the need for an American-built and American-operated merchant marine. Their experience in two great wars has shown them that an adequate merchant marine under the American flag is indispensible to the country's general welfare, and the country recognizes that its economic, political, and industrial position is determined to a great degree by its place upon the seas. Wholehearted support of American shipping through its patronage by the American traveling public, the exporter, and the importer is a deciding factor in the successful operation of any merchant marine.

Definitions of Shipping Terms

Trade: Water-borne trade only is considered in this chapter.

(1) *Direct foreign trade:* Trade of the United States with another country carried on by the vessels of either country.

(2) *Domestic trade:* Trade between ports of the United States or between ports of the United States and ports of its possessions. With the exception of trade with the Philippines and Virgin Islands, ocean-borne domestic trade is known as "coastwise trade." Between two ports on the same coast, it is called "coastal trade"; between a port on the East Coast of the United States and a port on the West Coast, "intercoastal trade." Other domestic water-borne trade is on the Great Lakes, inland rivers, canals, bays and sounds, and harbors.

(3) *Foreign trade:* Trade of the United States and of its possessions with foreign countries.

(4) *Indirect foreign trade:* Trade of the United States with another country when carried by the vessels of a third country.

Knot: A measurement of speed in nautical miles per hour. By popular usage, a nautical mile is 6,080.27 feet, or about 1⅙ statute miles.

Tonnage: There are several kinds of tonnage used in shipping. Unless otherwise stated, ton equals 2,240 pounds.

(1) *Deadweight tonnage:* The combined weight of cargo, fuel, water, stores, passengers and baggage, crew and their effects—in other words, the weight of everything the ship can carry.

(2) *Displacement tonnage, loaded:* The weight of the ship and all that it carries, and equal to the weight of water displaced by the ship when floating free.

(3) *Displacement tonnage, light:* The weight of the ship, excluding cargo, passengers, fuel, water, stores, dunnage, and such other items which are necessary for use on a voyage.

(4) *Gross tonnage:* The internal capacity, less certain allowable de-

ductions, of permanently enclosed spaces throughout the ship in cubic feet, divided by 100.

(5) *Net tonnage:* Gross tonnage less deductions for spaces occupied by fuel, water ballast, stores, ship's crew, and other similar spaces not devoted to the carriage of passengers or cargo.

Ship, vessel: These two terms are used synonymously.

(1) *Cargo vessel:* A vessel designed and built primarily for the carriage of cargo, although it may carry passengers under existing law not to exceed 12 in addition to the crew.

(2) *Combination vessel:* A vessel designed and built to carry both passengers and cargo.

(3) *Industrial carrier:* A vessel owned or chartered by an industry and used primarily in the transportation of its own products.

(4) *Oil tanker:* A vessel designed and built for the carriage of oil, generally in bulk, and frequently owned by the company whose oil it transports.

(5) *Passenger vessel:* A vessel designed and built primarily for the carriage of passengers, although it may carry some cargo.

(6) *Tramp ship:* A vessel following no regular routes or schedules but which picks up cargo wherever business offers.

United States Shipping Board: A board of five commissioners created under the provisions of Section 3 of the Shipping Act of 1916. Abolished by an executive order of June 10, 1933, and activities transferred to the Department of Commerce as the United States Shipping Board Bureau of the Department.

United States Emergency Fleet Corporation: A corporation organized by the United States Shipping Board on April 16, 1917, to carry out the board's ship-construction program. The name changed by act of Congress, February 11, 1927, to United States Shipping Board Merchant Fleet Corporation.

United States Maritime Commission: An agency of five members created under the provisions of Section 201 (a) of the Merchant Marine Act of 1936.

30

The Railroad Industry

Evolutionary Growth of Transportation

Early history of transportation. It is a far cry from the modern Pullman express, carrying hundreds of passengers in comfort and safety at a speed of more than a mile a minute, to the struggles of primitive man to drag a heavy load on a stick or hollow out a rude boat from a tree trunk. Modern transportation by land goes back to the first use of the wheel, undoubtedly the most important single discovery in the history of mankind. Probably the rolling of tree trunks or of rounded stones first gave the idea. By the time man advanced to the point of cutting the trunks of trees into short lengths for easier motion, he was taking the first step toward all that has developed of present-day industrial and social life.

It was perhaps thousands of years after the first rough canoes before anything resembling a ship ventured on the open seas. The Phœnicians sailed the Mediterranean selling tin, and through their efforts, trade routes were opened from the Far East to what is now the Italian peninsula. On land, commerce was carried on over trails and rough roads until the Romans constructed the first great system of overland highways, many of which are still in use.

Basic discoveries. The wheel gauge of Roman carts and wagons in Great Britain became fixed at 4 feet, 8½ inches (modern measure). When the first crude rails of stone were laid in England, 200 years ago, they were built to accommodate horse-drawn wagons, which still used this ancient gauge. This is the origin of the standard width of track on both English and American railroads. The flanged wheel had not yet arrived, and the rails were grooved to keep the wagon wheels from running off the track.

Modern transportation by rail and by water had its genesis in the invention by James Watt, of Glasgow, Scotland, in 1769, of the first practicable steam engine. The tremendously powerful force of steam, brought to the aid of man, revolutionized industry and commerce alike. Its first uses were in the English textile mills, but there were early experiments made by James Trevithick and Timothy Hackworth with the idea of applying steam power to transportation.

First practicable steam locomotive. It was not until 1825 that a practicable steam locomotive was put into successful operation, and the honor of its invention belongs to George Stephenson, of Newcastle-on-Tyne. His crude little *Locomotion* hauled coal on the Stockton and Darlington Railway, a 14-mile coal tramway. A far more efficient engine, also developed by Stephenson, was the famous *Rocket*, built in 1830 for the Liverpool and Manchester Railway, the first road to serve as a public carrier of passengers and freight.

Development of the American Railroad

Transportation in colonial days. In the United States, the use of steam in transportation followed close on the heels of its development in England. Communication between the colonies, and later the states, along 1,000 miles of seaboard had been limited to rough post roads, coastwise sailing vessels, and watercraft on inland rivers, supplemented by a few canals. Most notable of the latter was the Erie Canal, opened in 1826, connecting the Hudson River at Albany with Lake Ontario at Oswego and Lake Erie at Buffalo by what has become known as the "water-level route." The canal was shallow and closed almost half the year, but by means of it the Great Lakes and a vast interior region were opened to communication with the fast-growing port of New York.

First rail lines in America. Perhaps the earliest use of rails in this country was a line of less than 1 mile in length laid down by Thomas Leiper, in 1809, to connect his quarries on Crum Creek, near Philadelphia, with the Delaware River. Seventeen years later a 3-mile tramway was built from West Quincy, Massachusetts, to the Fore River wharves, and over this line horses drew the great stones used in building Bunker Hill Monument.

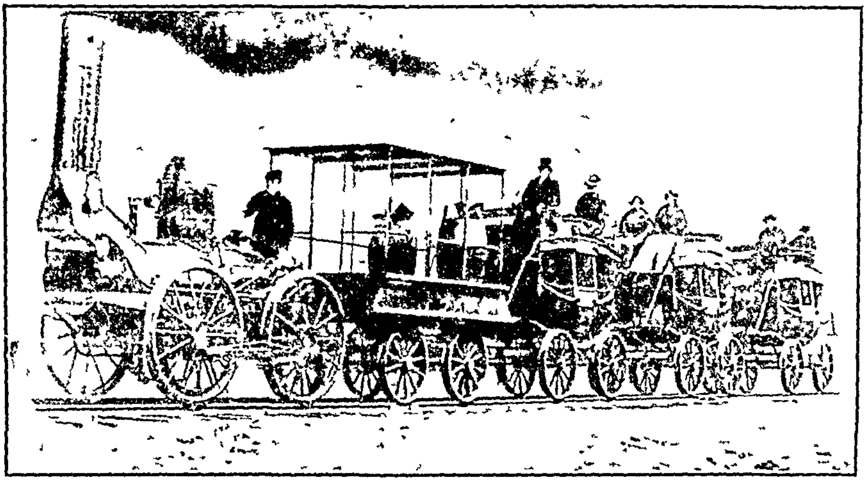
The first two tramways accessory to coal mining were at Mauch Chunk and Honesdale, Pennsylvania. The latter, owned by the Delaware and Hudson Canal Company, connected the mines of that company with the head of its canal at Honesdale, and over this piece of track the first steam locomotive ever operated in America made its appearance on August 8, 1829. This was the *Stourbridge Lion*, built in England. The Interstate Commerce Commission authorized the abandonment of the old track at Honesdale on August 1, 1931.

First American railroad. What was actually the first American railroad is a moot question, depending on how the term "railroad" is defined. The first to be organized in corporate form was the Mohawk and Hudson, earliest predecessor of the present New York Central system. This company was chartered April 17, 1826, with authority to build a railroad between Albany and Schenectady, a distance of 17 miles. The Baltimore and Ohio was incorporated in 1827, with the ambitious project of building a 300-mile railroad from Baltimore to the upper Ohio River, to be operated with relays of horses. The first 14 miles of track, from Baltimore to Ellicott Mills, were put into operation on May 24, 1830, first with

horses and then with a tiny steam locomotive, the *Tom Thumb,* built by Peter Cooper of New York.

Meanwhile the South Carolina Canal and Railroad Company, chartered December 19, 1827, began construction in January, 1830, of a line 130 miles long from Charleston to Hamburg, across the Savannah River from Augusta, Georgia. This was, at the time, the longest continuous railroad in the world. Upon it ran the first American-built locomotive for practical service, the *Best Friend of Charleston,* which was built and shipped to Charleston by the West Point Foundry, New York City, and put into service Christmas Day, 1830.

The Mohawk and Hudson encountered great difficulties and experimented with inclined planes at both ends of the line. It was finally opened for service in August, 1831. Its first train between Albany and



Courtesy New York Central System

Fig. 1 The DeWitt Clinton

Schenectady was hauled by the locomotive *De Witt Clinton,* also built by the West Point Foundry.

The period of expansion. Railroad development was rapid in the next few years, with New England a particularly active field By 1841, one could travel from Boston to Albany by rail, and in the following year on to Buffalo. The Hudson River formed an admirable pathway between Albany and New York, and in 1851 these two cities were also connected by rail. One route followed the river, and the other, completed in 1852, went inland by way of White Plains and Chatham The Michigan Southern and the Michigan Central, racing construction west from Buffalo to the south and the north of Lake Erie, respectively, reached Chicago in the same year, 1853. By 1856, one could go by rail from New York to the Mississippi, and soon after to St Joseph, Missouri.

New construction lagged during the Civil War period but immediately thereafter was resumed with great energy. The center of chief activity was in the West, where track-laying gangs of the Union Pacific, working west from the Missouri River, and of the Central Pacific, working east from California, linked up the first transcontinental line on May 18, 1869, at Promontory, Utah. Other transcontinentals followed; new roads and branch lines were filled into the railroad map of the East and of the South.

Then began the natural and obvious era of consolidation. The series of short roads from New York to Buffalo by way of Albany was united, in 1853, into a single system, which in due time was extended to Pittsburgh, Cincinnati, Detroit, Chicago, and St. Louis. Similarly, the roads forming a main stem line across Pennsylvania were grouped into a single system, which later reached these same cities. Other unifications followed, to the east, south, and west.

Many of the principal lines were double-tracked, and in a few instances four main-line tracks were laid. Immense capital investments were made in reducing the curves and heavy grades of early construction, in strengthening bridges, replacing old trestles with steel and concrete, abolishing grade crossings, improving roadways, protecting operation with mechanical signaling systems, laying heavier rail, and constructing great terminal yards and larger and more adequate stations. Locomotives became more powerful, cars more commodious and comfortable. The first Pullman sleeper was built in 1859. Many forms of equipment were standardized. Devices in great variety were installed for the safety and convenience of passengers; these included the automatic air brake, more efficient car couplers, the vestibule platform, steam heating and electric lighting of cars, and recently the automatic train stop and air conditioning.

Both operating economies and a vastly improved public service have resulted from these applications of inventive ingenuity, and the process has steadily continued, even through years of depression. In fact, the gross capital expenditures of Class I railroads in the years from 1920 to 1940 were in excess of $10,400,000,000.

With these developments came the rise of great labor organizations, the intense competitive traffic struggles, the enactment of the Interstate Commerce Act of 1887, and the era of Government regulation. All these phases of the history and growth of rail transportation in America require thoughtful study for a clear understanding of the position the railroad industry has now reached and of the future course it is to take in our economic and industrial life.

Electric operation of railroads. In certain well-known instances, electrification of limited areas of steam railroad lines raises the question of how far we may expect this field of development to be carried. The problem is far from simple, because of widely varying conditions and inconclusive experience. The physical aspects of operation in congested urban districts differ essentially from those on open-country routes. Both engineering methods and traffic conditions are constantly changing.

making it impossible to forecast results with the certainty desirable when fundamental changes of transportation method, involving immense capital expenditures, are proposed.

Because of these difficult practical problems, physical and economic, progress in electrification has been slow. In the 46 years since the first installation, in 1895, on the Nantasket Beach branch of the New Haven road, at Boston, a small percentage of the total route mileage of steam railroads in the United States has been electrified. Among the best-known installations are the New York Central to Harmon, New York, the Pennsylvania from New York to Washington, and from Philadelphia to Harrisburg, the New Haven to New Haven, the Hoosac tunnel, the Baltimore tunnel, the Detroit River tunnel, and certain mountain divisions in the Appalachian and Rocky Mountain ranges.

The decisive factors leading to electrification projects thus far have been primarily physical. They were dictated by local conditions, under which continued steam operation became impracticable for reasons of public convenience, safety, and expeditious service. Some of the places for which electrification is particularly advantageous are densely populated urban and suburban areas, served by short lines with complicated trackage problems and numerous passenger stations; regions in which several such urban areas are near together, so that combined steam and electric operation between them would be uneconomic; long tunnels, where the smoke and steam problem is serious; and sections of road where heavy grades limit schedules and require uneconomic use of power.

The principal economic factors involved are, of course, the relation of possible operating economies and possible increased revenues to the interest requirements, maintenance, taxation, and other costs of the new capital expenditure. Realization of increased revenues, traceable to electrification, is a problem greatly complicated by the growth of other modes of transportation, by the increased use of highways and waterways, which has retarded the normal rate of increase in freight traffic in recent years and resulted in a very substantial decline in the actual volume of passenger traffic.

With regard to operating economies, it is to be noted that comparisons of tractive power and possible train loads, under the two methods, have been materially modified by improvements in steam locomotives Maintenance cost is probably slightly in favor of electric locomotives, but on the basis of experience thus far, very little difference between the two will be found in the rates of depreciation due to use and of obsolescence due to age.

Over long-distance routes, where freight as well as passenger traffic is handled in substantial volume, electrification will probably not be in general use for a considerable time. It will necessarily involve a standardizing, in fundamental features, of types of electric installation, in order to permit interchangeable use of power at joint terminals and on connecting lines. So far as can now be foreseen, electrification of steam lines is likely to be determined in each instance by the existence of physi-

cal conditions to which it is well adapted and which render steam operation, under these circumstances, impracticable or less efficient by comparison.

The past 40 years have seen the rise and fall of electrically operated interurban railroads, which formerly competed with steam roads for both passengers and for package freight that are now practically extinct.

Leaders in the field. The human element has played an extraordinary part in the development of railroad transportation, both in the vision and energy of promoters and executives and in the exceptionaly high quality of railroad labor as a whole. With the early days of American railroading are associated the names of such pioneers as Commodore Cornelius Vanderbilt, of the New York Central, Thomas A. Scott, of the Pennsylvania, John W. Garrett, of the Baltimore and Ohio, and John Murray Forbes, the driving force behind the construction of the Michigan Central; and a little later, General Grenville M. Dodge, of the Union Pacific, Henry Villard, of the Northern Pacific, Collis P. Huntington, of the Southern Pacific, and James J. Hill, of the Great Northern.

The day of the great individual pioneer and builder soon passed, and the next period of growth called for a somewhat different type of leader to expand, reorganize, and improve upon the work of the pathfinders. Today, rail transportation is no longer a daring adventure but a complex problem of administration for the control, direction, and improvement of the country's railroad systems within the limits of intricate Government regulations and under conditions widely different from those of the early days. The list of executives is a long one and contains many distinguished names. They have been, and are, assisted by a great army of officers unknown to fame and of loyal supervisors and workingmen, upon whom rests the daily responsibility of safe and efficient operation.

Economic Significance of Railroads to American Commerce

Commerce before the railroads. Industrial expansion in the United States has been very largely determined and shaped by the development of means of transportation. Before the coming of railroads, our commerce was carried on chiefly by water. Of the 25 states in the Union in 1825, 18 bordered on the Atlantic Ocean or the Gulf of Mexico; the others touched the Great Lakes, the Ohio River, or the Mississippi River. The population was 12,000,000, an average of 7 persons to the square mile.

Agricultural production was limited mainly to the needs of local markets, for lack of transportation. Factories were few and small; most goods were still produced by hand labor. There was no incentive to develop labor-saving machinery, either on the farm or in mills, until the products in quantity could be widely and cheaply distributed to distant consumers.

By 1811, there were 37,000 miles of post roads in the United States, but it cost $100 and 20 days of time to move 1 ton of freight between Albany and Buffalo, and $140 to move it over the Alleghenies between

Philadelphia and Pittsburgh. Our forefathers turned their attention to canals for relief, and before the canal era passed its peak, about 1840, some 5,000 miles of these artificial waterways had been constructed, at a cost of $150,000,000. On the Erie Canal, the time required for a shipment between Albany and Buffalo was reduced to 10 days and the cost to $10, later to $3, a ton.

Influence of railroads on industrial development. Along the lines of the early railroads commercial and industrial enterprises sprang up, many of them to attain vast proportions in later years. The Western wilderness was opened up, and control was gained over the Pacific Coast. Railroads, more than any other one factor, made possible the immense industrial development of the United States.

They brought about a wide distribution of manufacturing industries. In the early period, manufacturing was limited chiefly to the section east of the Alleghenies and north of the Potomac River. Freight rates were adjusted so as to encourage the movement of raw materials eastward and of finished products westward.

Extension of the railroads westward created a new situation, making it possible to locate factories nearer to the sources of raw materials. To meet this situation, freight rates were readjusted, and the effect was to encourage development of industries in the newer sections of the country. Manufacturers in the older locations, farther from supplies, derived the greater benefit from low rates on raw materials, but those in the newer locations had the advantage of a shorter mileage haul. Moreover, the lower rates on finished products made it possible for industries, wherever located, to distribute their merchandise to markets at a distance as well as near at home.

These changes, together with more efficient service, have been very important factors in the rapid development of manufacturing activity in the West and South. In fact, the highest percentages of gain in total value of manufactured products in the period from 1914 to 1927, for illustration, were in the Far Western, the Middlewestern, and the South Atlantic states. In addition, the expansion of industries west and south brought a large industrial population close to the great farming areas, providing new markets close at hand for the produce of the farms, and the volume and value of agricultural production rose rapidly.

The tendency at the present time is toward a scale of rates based on mileage, the effect of which is to confine manufacturing and distribution within narrower spheres. Industries which are nearest to both raw materials and markets will have the advantage of lower freight costs, because of a shorter haul, on both their materials and their finished products.

Traffic conditions. Railroad traffic reached its peak in 1926. In that year, railroad performance was equivalent to moving 1 ton of freight 486,265,000,000 miles, or 4,173 tons an average distance of 1 mile for each inhabitant then living in the United States. In addition, the railroads handled the nation's mail and express and transported 862,000,000 passengers an average distance of 41 miles.

Increased expenditures by the Government on waterways, the growth of motor-vehicle transportation on public highways, and the economic depression starting in 1929 affected transportation by rail, so that total tons carried increased 22 per cent, while freight revenues increased 4.1 per cent in the decade beginning with 1921. In this same period, passengers carried decreased 32 1 per cent and passenger revenues 36 8 per cent. It is interesting to note that, in the period from 1915 to 1928, registration of motor trucks in the United States increased from 136,000 to 3,114,000, while registrations of all passenger-carrying motor vehicles increased from 2 309,666 in 1915 to 23,121,589 in 1929.

Average freight rates per ton-mile in the United States in 1930 were 80 per cent of those in France, 61 per cent of those in Germany, and 41 per cent of those in the United Kingdom. At these rates, the most expeditious service in the world is rendered For illustration, perishable products dispatched from Chicago in the evening are delivered in New York the third morning thereafter; those sent from California to Atlantic Coast points arrive on the eleventh morning Merchandise leaving Chicago in the evening is delivered in St Paul the second morning thereafter. Shippers in St. Paul or Minneapolis may depend upon delivery anywhere within 300 miles by the next day. On the basis of number of days in transit, which is the important factor, freight shipments within a radius of 300 miles make very nearly as quick time as mail or express, and this is typical of railroad service practically anywhere. All the more important industrial plants are reached by railroad sidings which permit direct loading and delivery.

There was an increase of 13 per cent in freight-tons hauled per average train and of 65 per cent in average gross ton-miles per train-hour in the decade 1920 to 1929, with a 27 per cent saving in tons of coal burned. These figures represent standard tests for the measurement of operating efficiency A striking illustration of the more economical operation made possible by improved power may be seen in the fact that, in 1920, on the New York Central, the route of the *Twentieth Century Limited* between Harmon and Chicago was divided into 7 districts, requiring 7 engines for the trip, while today there are but 2 districts and 3 engines to cover the entire distance, hauling a heavier train. On the Northern Pacific, within the last 5 years, 13 engine districts have been reduced to 3, including one continuous run of 904 miles; while on the Southern Pacific, for another illustration, the 815 miles from Los Angeles to El Paso are made in a single engine run.

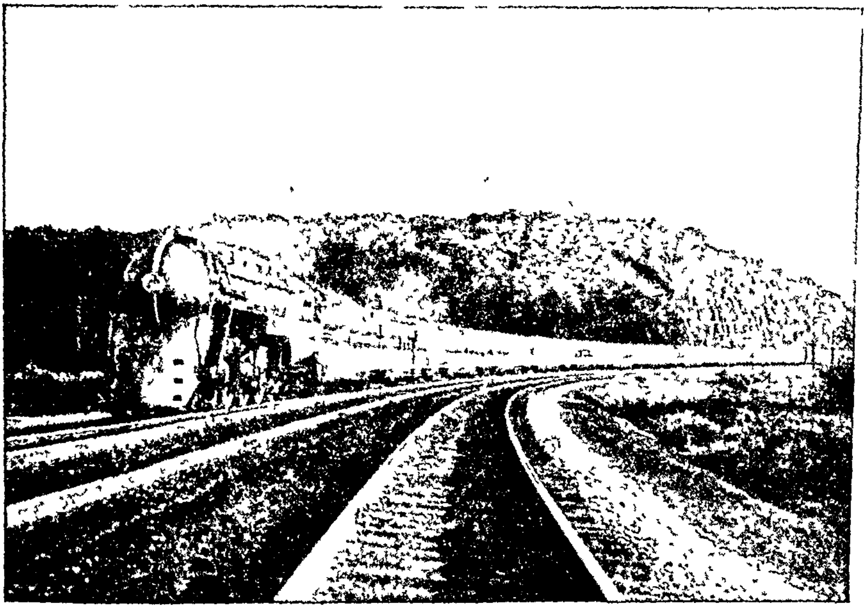
Because of the decline in freight earnings due to the growth of motor-truck operations, it is the belief of railroad executives and of many economists that the further development of rail service and of revenues adequate for maintained efficiency will depend chiefly upon the course of public policy in respect to use of the highways, constructed and maintained at public expense. It is held, from the railroad point of view, that a just and nondiscriminatory attitude as between these two forms of

transportation service requires a reasonable equalizing of conditions in respect to taxation and regulation of rates and operation.

In 1939, despite increasing competition from other forms of transportation, it is estimated that the railroads handled about 62 per cent of the country's freight tonnage.

Present Status of Railroads

Internal organization. American railroads, through their many interrelations and the similarity of their operating, traffic, and financial problems, have developed forms of organization substantially alike in general pattern, although necessarily differing in details. The internal organiza-



Courtesy New York Central System

Fig. 2. The Twentieth Century Limited.

tion of the New York Central, which is here used for illustration, may be taken as typical in essentials of all the principal systems.

All authority for management of the property, under the bylaws of the corporation, is delegated to a board of directors, 15 in number, elected by the stockholders. The functions of the board, when it is not in session, are exercised by an executive committee of 7, which elects its own chairman.

The board of directors elects a president, who is the chief executive officer and exercises general supervision over all the company's activities. It also appoints a secretary, a general treasurer, a treasurer, a comptroller, and their chief assistants. The general treasurer and the treas-

urer are the custodians of company monies and securities. The comptroller has supervision of accounting procedure and is responsible for keeping the company's books and records, in accordance with the requirements of the Interstate Commerce Commission and other regulatory bodies.

Since the president cannot attend personally to all the company's diversified operations, there has grown up what is known as the "departmental" form of organization. A vice-president is at the head of each department. There are the following departments: finance, operating, traffic, law, public relations, accounting, improvements and development (physical), purchasing, and personnel.

The vice-president of finance is in charge of the financial operations of the company.

The operating department is by far the largest. It is in direct charge of the railroad's service to the public, the operation of trains and maintenance of roadway, bridges, buildings, cars, and locomotives. Principal subdivisions of the railroad are in charge of general managers, assisted by general superintendents, division superintendents, chief engineers and division engineers in charge of road maintenance, superintendents of motive power and rolling stock and division master mechanics, signal engineers, superintendents of telegraph service, and many supervisors of further subdivided functions.

The traffic department is responsible for selling the services of the company to the public. Its objective is to produce business which will earn net revenues, above operating and overhead expenses and taxation, sufficient to pay interest on the company's indebtedness and dividends to stockholders who have invested their capital in the business. Assisting the vice-president are traffic managers, general freight agents, general passenger agents, and their assistants, including officers in charge of such special services as mail, express, baggage, industrial development, and "off-line" traffic soliciting agencies throughout the country.

The law department's many and varied responsibilities have been greatly enlarged by the far-reaching extent of public regulation. Nearly every activity of the company comes under the scrutiny of its legal staff, to make certain that it does not conflict with some of the many thousands of national or state laws or municipal ordinances. The law department seeks to protect the company from unjust claims and conducts whatever litigation may be necessary. Here are found such officers as general counsel, general attorneys, general solicitors, and their assistants.

The accounting department has charge of collection of the company's revenues and their disbursement as authorized. It makes the classified record of receipts and expenditures, and compiles an immense volume and variety of regular and special reports for the information of the railroad's many other departments, as well as for numerous Government bureaus. The officers in charge are a vice-president, the comptroller, the general auditors and their assistants, auditors of various classes of accounts, bookkeepers, and statisticians.

The improvements and development department plans and carries out

improvements authorized by the board of directors. Under this head come extensions of line, new buildings, and additions to permanent structures.

The purchasing department supervises the expenditure of many millions of dollars each year in the authorized purchase, to the best advantage, of materials and supplies, ranging from thousands of tons of coal to pencils and twine. In this department are the general purchasing agent, the purchasing agent, and his assistants, and the general storekeeper and his staff.

The vice-president in charge of personnel has charge of all negotiations between the company and the labor organizations in respect to wages, working time, and general conditions. In addition, he either promotes or coöperates in certain of the beneficial, recreational, and educational activities of the employees.

Most large systems are divided into geographical units, originally separate railroads which have been brought into the system through leases or other means of control but retain in certain respects their former corporate identity. Each of these geographical units is administered by a vice-president, assisted by a complete organization of its operating, traffic, accounting, and other departments, similar in general to that of the system as a whole.

Methods of financing. The early railroads in this country were looked upon, for the most part, as financially risky experiments. Population was sparse and money scarce. Promoters of railroads had great difficulty in raising the capital for construction. There was, nevertheless, a rapidly growing public demand for this new form of transportation once its immense possibilities were realized. Several states and many counties and municipalities extended financial aid in order that lines might be built through the particular sections in which they were interested. Six pioneer roads west of the Mississippi received land grants totaling more than 150,000,000 acres, mostly valueless wilderness at the time, as well as cash loans exceeding $60,000,000, nearly all of which has been repaid with interest. In return, the railroads were required to haul troops, Government passengers, and mail at reduced rates or free. Some of the land-grant roads are still rendering this free service, while others are giving it at half rate.

As railroad development went forward apace, new issues of stock were sold to provide funds, but in the later period of great expansion, it was necessary to borrow the larger part of the capital required.

Financing of the purchase of locomotives, passenger, and freight cars is accomplished by issue of equipment trust certificates, a method much like the installment plan used by the buyer of a motorcar or piano, in order that he may have the use of his purchase while paying for it.

The severe depression which occurred in the business and economic conditions of the country following the decade of the twenties, together with the increasing competition and development of other forms of transportation, brought about a serious decline in the revenues of railroads during the past 10 years. Many companies with heavy capitaliza-

tion, particularly in fixed interest-bearing bonds, were unable to meet their obligations and sought relief in the courts. As of the end of 1939, companies controlling approximately one third of the railroad mileage in the country were in process of reorganization. The capital structures of these companies will be adjusted to meet the changed conditions, and this will be particularly true as regards the interest-bearing debt.

Amount of capital invested. The total investment in road and equipment of all steam railroads in the United States, in 1938, was $26,502,582,000, according to statistics published by the Interstate Commerce Commission. This figure includes terminal and switching companies leased by the railroads. The par value of capital stock of Class I railroads (operating companies having revenues of more than $1,000,000 per annum) was $8,149,342,285. The long-term debt, also representing capital invested, was $10,352,646,039. Current liabilities outstanding were $2,555,903,042. Corporate surplus was $2,563,879,462, practically all of which is used currently in the railroad business or represents investments not yet capitalized. There are approximately 868,231 owners of stock of all Class I line-haul railroads in the country.

The New York Central Railroad Company was financed in the early days largely by the stockholders Today, the system represents about 570 predecessor corporations and operates about 11,000 miles of main and branch lines in 11 states and 2 provinces of Canada. The property investment at the end of 1940 was $2,043,576,808, and the total capitalization $1,211,064,842. Of this capitalization, 46 per cent was represented by capital stock, the remainder by bonds and other fixed debt. There were 62,345 stockholders at the end of 1940, of whom 61,145 were located in the United States and 1,200 abroad

Number of persons employed. The average number of employees on Class I railroads for the year ended December 31, 1940, was 1,026,956; in the preceding year, the number employed was 987,675. In 1920, the year in which Government operation ceased, the average was 2,022,832. The total compensation of these employees in 1940 was $1,964,480,706, an average of $1,913 per employee; in 1939, it was $1,863,333,736, an average of $1,887 per employee.

The decrease in forces employed on the railroads has not been due wholly to the business depression of 1929 to 1932. In part, it has been the result of improved operating efficiency, chiefly through modern-type locomotives, improved track, new or reconstructed terminals and yard facilities, and so forth; and to a considerable extent to the increasing competition of freight trucks and passenger buses operating on the public highways.

Effect of labor unions. In the early days of railroading, relations between managements and employees were largely those of the "boss" and the individual workman. There were great railroad strikes in the late seventies, and as early as 1888, Congress passed the first act creating boards of arbitration to assist in settling differences. It was not until some years later, however, that labor unions became a strong and permanent factor to be reckoned with in railroad operation.

With the coming of large and still larger organization on the part of both capital and labor, questions of wages, hours, and working conditions passed from the stage of individual bargaining to that of negotiations through representatives and were covered by formal agreements for whole classes of employees. Most of the railroad crafts built up their organizations independently and have remained distinct from those in other industries.

Today, about 94 per cent of the total railroad personnel is represented in labor organizations or associations, including those formed in the mechanical crafts after the shopmen's strike in 1922. The remainder consists chiefly of officers, traffic solicitors, and the legal and engineering forces. Agreements with the leading organizations are necessarily designed to protect the conditions and rights of classes of employees rather than of individuals, but when exceptional conditions arise, a certain amount of latitude is allowed for variations through special understandings.

Because of the public-service character of railroad operation and the seriousness of possible interruptions, Congress early took cognizance of relations between managements and employees, under a broad interpretation of its right and duty to regulate interstate commerce. Outstanding instances of its exercise of control in respect to labor are described later.[1] There has been a succession of boards or commissions with various functions of conciliation, arbitration, or decision regarding disputes in railroad service

The effects of labor unions, in a general view of railroad development and problems, may be summarized as an approximate standardizing of conditions, in essential features, by regions and groups of roads, as the result in part of agreements between the carriers and organized employees and in part of legislation and the rulings of official bodies. In brief, the development of organized labor on the railroads has, in certain important respects, been bound up quite closely with that of public regulation. This situation has necessarily resulted in a certain limitation of freedom of action on the part of the railroads. This limitation, however, is inevitable in varying degrees as industrial operations become large and complex, particularly in those industries of a public-service character.

In recent years, decisions of the National Railroad Adjustment Board, which was created by the Railway Labor Act, as amended in 1934, have had serious effects upon railroad operating costs. That board is composed of four divisions. The first division represents employees in the engine, train, and yard service; the second division, employees in shops, engine houses, and repair yards; the third division, employees in clerical and station service, telegraph service, dispatching service, maintenance of way, dining service, and signal maintenance; and the fourth division, employees in the marine service and other branches not represented by the other three divisions. Disputes arise over the intent or meaning of rules in the agreements applicable to the several classes. Notwith-

[1] See the section on "Important Legislation Affecting Railroads," p 672.

standing the fact that most of the rules have been in effect and applied for many years on certain roads without controversy, when decisions are rendered in disputes submitted from other roads, the interpretations are being extended to all roads, so that differing conditions and practices are disregarded. In the past, it had been the pride of both management and committees representing employees to compose any differences to their mutual satisfaction, but the decisions of the several boards are making it increasingly difficult, if not impossible, to dispose of disputes locally, unless the interpretation most favorable to employees is adopted.

Important companies operating. A total mileage of 232,748 (main tracks) and gross revenues of $4,296,690,653 were reported for 1938 by Class I railroads in the United States. Some of the largest systems, with geographical sections covered and miles operated, are as follows:

New England:	
Boston & Maine	1,910
New York, New Haven & Hartford	1,864
Central Eastern:	
Pennsylvania	10,261
New York Central	10,941
Baltimore & Ohio	6,382
Erie	2,267
Southern:	
Chesapeake & Ohio	3,110
Norfolk & Western	2,191
Southern Railway	6,594
Atlantic Coast Line	5,101
Northwest:	
Chicago & North Western	8,324
Great Northern	8,069
Chicago, Milwaukee, St. Paul & Pacific	10,874
Chicago, Burlington & Quincy	8,973
Central West:	
Southern Pacific	8,630
Union Pacific	9,901
Atchison, Topeka & Santa Fe	13,413

These 17 lines, operating 51 per cent of the total Class I mileage, earned 59 per cent of the gross revenues. Additional lines, each of which earned in excess of $80,000,000 gross revenue and operates more than 4,800 miles, are the Louisville & Nashville, the Chicago, Rock Island & Pacific, and the Missouri Pacific.

If the proposed consolidation of the country's railroads into some 20 major groups is brought about, the lines here listed will form the basic structure.

Comparison of Railroading with Other Important Industries

The most conspicuous difference between the status of railroading and that of other types of industry—manufacturing, commercial, and agricultural—is in respect to the effects of Government regulation, elsewhere discussed. There are other interesting points of comparison, however,

having to do with size, character of the employment, and the investment status of securities.

Size. The only single industry approaching the steam railroads as regards capital investment is the motor industry. Since the railroads finance and build their own roadways, a proper comparison should include the investment in public highways regularly used by motor trucks and busses as well as private cars. Authoritative figures are not obtainable for the total investment in busses and trucks, but an estimate by the National Automobile Chamber of Commerce placed the total investment in rural highways at the end of 1930 at $12,500,000,000. It is particularly interesting to note that this is approximately the same as the total investment in roadway by the steam railroads of the country, since it is generally accepted that about one half the total railroad investment of over $25,000,000,000 is represented by roadbed and track. This comparison takes no account of city streets, also used by motor vehicles, upon which the estimated value was placed at $20,000,000,000. By 1940, the expansion of highways had been so great that the estimated investment in rural highways was then given as $25,000,000,000, or roughly the same as the total railroad investment.

Character of occupations. The most obvious distinctions between employment on railroads and in other industries, apart from certain regulations already referred to, are in the nature of the industry itself. Employees in train service are under what is called "distant supervision," rather than under immediate supervision, and are therefore, to a considerable extent, on their own responsibility. Judgment and decision are required in the expeditious and safe handling of trains and also in the dispatching, signaling, and switching operations. Observance of safety rules and contacts with the public in both train and station service involve the personal equation to a high degree Railroad functions are in very slight degree of the mechanized, mass-production type. The requirement, and therefore the opportunity, is for men of character, experience, and ability. In brief, the individual is of primary importance.

Status of securities. General statements must be qualified, of course, by the varying experience of different roads and the relative positions of the many issues of stocks and bonds, but it may be said that railroad securities as a class represent investment in the oldest of the major industries of the country and were long regarded as of exceptional stability, ranking next, in fact, to those of the United States Government. They are still widely distributed among millions of individuals, directly and through insurance companies, banks, savings banks, trust funds, and educational endowments to an extent not equaled by those of any other representative industry. It is of vital importance to these institutions, as custodians of the people's money, that the railroads be permitted to earn a reasonable return on these securities.

These securities held by banks and trust and insurance companies represent, if indirectly, the savings and investments of the people no less than do those owned outright by individuals. It is equally true that the will of the people, as expressed through legislative and regulatory

bodies, will determine to a large degree the future course of railroad development as an indispensable agent of commerce and will take a leading part in settling the problems of the status of railroad securities and of service under the new conditions of transportation which have arisen in recent years.

Important Legislation Affecting Railroads

The affairs of the railroads have been subject to Government regulation for many years, and this regulation probably extends to more phases of their activities than for any other business.

Early legislation. The greater part of early English and American railroad legislation was based on the analogy of the "King's Highway," the roads being treated as essentially public ways, with the owner companies operating over them as common carriers. Charles Francis Adams, Jr., in his *Railroads, Their Origin and Problems,* pointed out fundamental elements of error in this conception, and the resulting confusion in public policy and unsuitability of much of the early legislative dealing with the new mode of transportation.

Interstate Commerce Act. There was comparatively little special railroad legislation prior to 1870. Thereafter, a few states established boards or commissions, some chiefly to secure publicity and others with definite powers of regulation within state borders. In 1886, it was established, by a Supreme Court decision, that the Federal Government had the exclusive authority to regulate interstate commerce transported by carriers. Putting that principle into effect, Congress in the following year enacted the Interstate Commerce Act, based upon the theory that railroads, although privately owned, are charged with a public duty. The Interstate Commerce Commission, created by that act, has been functioning ever since and is generally recognized as one of the most powerful administrative bodies in the world.

The Interstate Commerce Act was designed primarily to prevent excessive charges and discriminatory practices, such as rebates to large shippers. Its scope and powers of enforcement have since been extended to embrace, not alone rate making, but nearly every railroad function—corporate, financial, and operating; and it has served as a pattern for regulating other kinds of carriers. State laws regulating railroads with respect to their intrastate business are now patterned very closely after the Federal act.

Among the many important subjects brought under Federal authority by the Interstate Commerce Act are the rates of railroads, which must be reasonably scaled and not unjustly discriminatory among the different users of railroad service; the divisions of through rates among participating railroads; the tariffs, or rate schedules, of the railroads, which must be published and kept on file with the Interstate Commerce Commission and which may be changed only upon due notice and filing with the commission; the accounts and statistical reports of the railroads, which must be kept in the manner prescribed by the commission; valua-

tion of railway property, upon which the commission has made extensive investigation and reports; and shipping documents and bills of lading, which must follow prescribed forms. Other important regulations, many of them restrictive in character, are the "commodities clause," forbidding railroads to transport goods owned by them, except goods used in railroad operations; the prohibition against ownership by railroads of interest in competing water carriers; the prohibition against granting of free transportation, except to railway employees; the "long-and-short-haul clause," prohibiting a higher charge for a shorter distance than for a longer distance over the same route in the same direction, except as relief may be granted by the commission in special cases; and numerous requirements in the interest of safety, including appliances on cars and locomotives, limitation of hours of continuous service, reporting of accidents, Federal inspection of locomotives and signals, liability for accidents to employees due to railroad negligence, and so forth.

Transportation Act of 1920. The Transportation Act of 1920 represented the first entry by Congress into the field of regulating railroad affairs in the interest of developing sound railroad systems, as distinguished from regulation to protect the shipping and traveling public from unjust practices of railroads. The Transportation Act recognized that the railroads should be allowed to charge rates sufficient to provide a "fair return" upon railroad property—a hope which, however, has never been realized, because of adverse business conditions and other factors. It required the authority of the commission for the building of new lines of railroad or the abandonment of old ones, for the consolidation of railroads, and for the issuance of securities by railroads Subsequent legislation has brought the subject of reorganization of railroads in bankruptcy fully within the scope of Federal authority. Under the Transportation Act, the concept of the railroads as a national transportation system has developed.

Competitive transportation agencies and Government regulation. Not long after the enactment of the Transportation Act of 1920, highway vehicles, public and private, became important competitors of the railroads and began to make serious inroads into their freight and passenger traffic. Heavy expenditures by Federal and state governments for the improvement of harbors and channels along the coasts and the Great Lakes and for the improvement of inland waterways, such as the Mississippi and Ohio Rivers and the New York State Barge Canal, greatly extended the operations of water carriers and increased their importance as competitors of the railroads for freight traffic. Improved highways brought forth millions of automotive vehicles, passenger and freight, private and public. These new competitors of the railroads derived advantages because they were free from the restrictions which regulated the railroads in their rates and practices. Still more important, they used highways or waterways provided by the Government either free of charge or at charges representing only a fraction of the cost of building and maintaining these facilities.

Even before 1930, important public groups, as well as the railroads,

began to urge that all forms of transportation, not alone the railroads, be subject to proper Federal and state regulation. The development of public opinion in this direction resulted in the enactment, in 1935, of the Federal Motor Carrier Act, administered by the Interstate Commerce Commission. Generally speaking, this act extends to common and contract motor carriers of passengers or property regulations as to reasonable and nondiscriminatory rates, publishing of rate schedules, new or extended operations, consolidations, accounts and reports, issuance of securities, safety, and so forth similar to those applied by earlier legislation to the railroads.

With the passage of the Transportation Act of 1940, Congress added water carriers to the growing list of major domestic commercial transportation agencies subject to regulation by the Interstate Commerce Commission.

Government subsidies to transportation agencies. A far-reaching proposal embodied in the pending legislation is that there should be an impartial fact-finding board to investigate and report upon the fitness of each kind of carrier to perform the various kinds of transportation service and the extent to which any carrier may be aided by subsidies or by facilities provided at public expense without adequate charge for use. If this board finds that the carriers on the inland waterways should pay reasonable tolls for the use of those waterways (which are now free of toll) and that those who use the public highways for profit should pay more than they now contribute toward the construction and maintenance of those highways, the effect upon competition among the railroads, the highway carriers, and the water carriers may be far-reaching. The need of Federal and state governments for additional sources of revenue is so acute that, if an impartial tribunal should find that motor and water carriers ought to make greater contributions to the public treasury, additional taxes upon these forms of transportation would almost surely be imposed.

Legislation affecting labor relations. The Transportation Act placed the control of labor's relations with the railroads under a Railroad Labor Board, but the labor sections of the act were superseded by the Railway Labor Act of 1926. The latter act recognizes collective bargaining and provides for mediation in railway-labor disputes by the Federal Mediation Board and, if this is unsuccessful, by special boards appointed by the President. Other legislation provides for "adjustment boards" to settle differences between railroads and employees concerning grievances and the interpretation of the written contracts covering wages and working conditions which have been so widely entered into between railroads and organizations of employees.

Taxation. Railroads are subject, generally speaking, to the same Federal, state, and local laws with respect to taxation as apply to business generally. However, because they own so much tangible property in the form of equipment, right of ways, track and buildings, the increasing burden of taxation, accompanied as it has been by declines in railway traffic, has been very severe. A related burden has been the

enforced spending of large sums for unproductive improvements, such as grade-crossing eliminations. In 1913, the railroads of the United States paid $118,386,859 in taxes, or 3.81 per cent of their gross revenues. In 1930, they paid $348,553,953, or 6.60 per cent of their gross revenues. In 1940, they paid $396,394,774; and their business had so declined that these taxes represented 9 23 per cent of gross revenues. A further source of tax burden has been special legislation for retirement pensions and unemployment compensation for railway employees, which grants greater benefits and imposes greater financial burdens than the Social Security Act does upon the railroads' competitors and upon industry generally.

Problems and Future of the Railroad Industry

The outstanding problems of the railroad industry today are those arising from the loss of much of its traffic. The first cause of this has been the development of new and competing forms of transportation on the highways, on the waterways, and in the air; this has both taken away traffic and forced reduced rates on traffic retained. The decentralization of industry and the displacement of commodities requiring railroad transportation by commodities requiring little or no railroad transportation (for example, the displacement of coal by oil and gas) have been important contributors. In 20 years, the railroads have passed from an almost complete monopoly of inland transportation to a situation where their competitors have made serious inroads upon their business.

The gross revenues, passenger and freight, of all Class I railroads declined from $6,279,520,544 in 1929 to $4,296,600,653 in 1940, a decline of 32.58 per cent Nevertheless, the railroads still carry by far the major proportion of the traffic, passenger and freight, transported by public carriers. During the 12 months ending December 31, 1939, motor carriers of passengers and property reported operating revenues of $1,048,000,000, as compared with $4,321,934,000 operating revenues of the railroads for the same period; thus of the total rail-motor gross revenues of $5,360,934,000, the railroads had 80.45 per cent and the motor carriers 19 54 per cent. However, the amount of transportation performed by private and public water carriers and by private motor carriers, such as private automobiles and the privately owned trucks of industries, is not included in these figures; it is probably much greater than that performed by for-hire motor carriers, but no accurate statistics are in existence.

The effect upon the railroads of the public's furnishing their competitors with highways and waterways free of charge or at charges less than a fair share of construction and maintenance costs cannot be too strongly emphasized. It is surprising but true that no comprehensive and impartial fact survey upon this subject is in existence, notwithstanding its obvious importance and the fact that it occasioned many controversial statements.

However, the Transportation Act of 1940 provides, among other things,

that a board of investigation and research be constituted, composed of three members appointed by the President, to investigate:

> (1) The relative economy and fitness of carriers by railroad, motor carriers, and water carriers for transportation service, or any particular classes or descriptions thereof, with the view of determining the service for which each type of carrier is especially fitted or unfitted; the methods by which each type can and should be developed so that there may be provided a national transportation system adequate to meet the needs of the commerce of the United States, of the Postal Service and of the National defense;
>
> (2) the extent to which right-of-way or other transportation facilities and special services have been or are provided from public funds for the use, within the territorial limits of the continental United States, of each of the three types of carriers without adequate compensation, direct or indirect, therefor, and the extent to which such carriers have been or are aided by donations of public property, payments from public funds in excess of adequate compensation for services rendered in return therefor, or extensions of Government credit; and
>
> (3) the extent to which taxes are imposed upon such carriers by the United States, and the several States, and by other agencies of government, including county, municipal, district, and local agencies.[2]

If, as the railroads believe, their competitors are subsidized and if, as should follow, those subsidies will decrease and ultimately disappear through the adoption of sounder Government policies, the railroads should regain much lost business. To attack the problem of competition among transportation agencies from the "subsidy" standpoint is far more important than from the standpoint of regulation. Regulation affects only carriers for hire and extends only to practices, without materially affecting operating costs, whereas the presence or absence of subsidies goes directly to the cost of doing business and affects private carriers, such as the privately owned motor trucks and barges of industries, as well as public, or "for-hire," carriers.

There has been a rapid awakening within the railroad industry to the need of more aggressive business policies to meet the challenge of the new competitors. Improvements in equipment and track and in methods of operation have speeded up railway service and made it safer and more attractive to the public. Greatly reduced rates and increased sales efforts have been put forward to sell railway transportation in the face of competition. More efficient internal organization in the industry has been developed. The railroads have recognized the previously neglected subject of public relations and the necessity of putting their case effectively before the public. There is every indication that these efforts are bearing fruit and will continue to do so. Far from proving that the railroads are obsolete as a means of transportation and will go the way of the canalboat and the stagecoach, their survival thus far against the inroads upon their traffic by business depression and growth of competitive agencies is a demonstration of the fundamental efficiency and economy of the railroad as a means of transportation. While it must be recognized that competitive forms of transportation are here to stay

[2] Source *Transportation Act of 1940*, Sections 301 and 302 (Public no 785)

and that the railroads will never again have the almost complete monopoly they once enjoyed, there is much in the present situation to justify the statement made by the Interstate Commerce Commission, in 1931, that "the railroads now furnish the backbone and most of the other bones of the transportation system of the country and we believe that this will be the situation for a long time to come."

31

The Automobile Industry

Growth of the Automobile Industry

Some 30 years ago, when a leader in the automobile industry predicted that 500,000 cars a year would be produced in the United States, a well-known banker stalked from the room in disgust and let it be known he thought such ideas deserved no consideration.

At the time, undoubtedly many more people agreed with the banker than with the motorcar manufacturer. The fact that, in every year since 1914, this hazardous estimate has been exceeded only goes to indicate the tremendously rapid development of the automobile industry and how it beggars all attempts at description.

Progress has been steady. During the depression decade 1930 through 1940, American factories in this country and Canada produced 36,878,759 passenger vehicles and trucks. Record output for any one year was made in 1929, when 5,621,045 cars and trucks were manufactured, with a wholesale value of $3,576,645,881, but the 5,000,000 mark was also exceeded in 1937, when 5,016,437 cars and trucks, valued at $2,971,027,641, were built. By January 1, 1941, there were 31,950,000 motor vehicles registered in this country, as compared with only 9,231,941 in 1920.[1]

Young in point of years, the automobile industry has already passed from adolescence to maturity. In its own magnitude, in its effect on other industries and callings, and in the changes it has wrought in a thousand different places, the automobile probably has contributed as much as, if not more than, any other single factor to our modern economic development.

Economic Significance of the Industry

Some idea of its size and scope may be gathered from a few bare facts regarding the industry. In value of its output, motorcar manufacture outranks all other manufacturing industries in this country. The export of automotive goods is the third most important item of the nation's foreign trade, being exceeded only by machinery and refined petroleum

[1] World registration of motor vehicles for 1940 was 47,000,000.

products. In response to these tremendous demands for its products, the industry has developed methods of manufacture and mass production previously considered beyond the realm of possibility. In addition, automobile merchants and manufacturers have developed, both in this country and abroad, one of the most extensive systems of distribution ever established.

Furthermore, net tangible capital invested in motor-vehicle manufacturing plants in the United States, at the close of 1939, amounted to $1,302,900,000, in addition to other large capital investments in companies manufacturing automobile parts, bodies, accessories, and tires and in dealer establishments.

The industry, 40 years ago only an idea shared by a few pioneering men, is now responsible for one seventh of the nation's pay envelopes. Directly or indirectly, it furnished employment in 1939 to 6,500,000 men and women. Of this number, about 443,000 are directly employed in the production of motor vehicles, while the others find work in related fields of endeavor or in industries and callings created by the motorcar industry. Sales and servicing of motor vehicles in 1939, for example, required more than 1,175,000 people. There were in that year more than 3,650,000 truck drivers and about 143,000 bus drivers. The remaining workers are employed in automobile parts and accessory factories, in petroleum refineries, in road construction and maintenance, as taxi drivers and chauffeurs, and in many other similar capacities.

In addition, the motor vehicle makes important contributions to other industries and producers of raw materials What the automobile means to such industries and producers can best be determined from the fact that it ranks as the most important customer for six commodities and for six forms of steel or iron. In 1939, for example, the industry used 90 per cent of the gasoline, 80 per cent of the rubber, 75 per cent of the plate glass, 23 per cent of the nickel, 34 per cent of the lead, and 40 per cent of the mohair consumed in this country. Furthermore, in the same year, the industry purchased 49 per cent of the strip steel, 51 per cent of the malleable iron, 33 per cent of the iron bars, 44 per cent of the iron sheets, 55 per cent of the alloy steel, and 18 per cent of all forms of steel produced in the United States. Other raw materials, most of which are demanded in increasing amounts by the automobile industry, included 68 per cent of the upholstery leather, 9.7 per cent of the aluminum, 13.7 per cent of the copper, 11.4 per cent of the tin, 10 per cent of the cotton, and 12.1 per cent of the zinc consumed in 1939 in this country.

The farmer has a valuable financial stake in the motor industry, which annually requires agricultural products, such as soybeans, corn, flaxseed, and many others, from some 2,500,000 acres.

It is estimated that the American people spend approximately one tenth of their national income for the purchase and operation of automobiles. Of this amount, about $4,000,000,000 is for the purchase of new and used cars and trucks, with approximately equal expenditures incidental to their operation, including such items as gasoline and oil, garage rent and

repair services, replacement parts, and automotive taxation and insurance. Recent studies have disclosed that, save only for food, housing, and clothing, persons in the United States spend more money for motorcar transportation than for any other single classification of merchandise. Thus, it is evident that this form of transportation is generally regarded in the United States as a necessary adjunct of the present mode of living, since it ranks in importance even with food in its place in the family budget.

Consequently, because of the great number of people for whom it furnishes employment, the market it constitutes for other industries, and the important role it plays in retail trade, the automobile industry obviously is a factor of great importance in modern American economy. When this industry is enjoying good business, a practical and also a psychological advantage is communicated to all these other kindred and related lines. Conversely, it is difficult for trade and industry generally to flourish in the face of a temporary recession in the automobile business.

Early History of the Automobile

Early steam-propelled road carriages. For many years before the automobile industry as such began to develop, steam locomotives were in general use on railroads in this country and abroad. Steam-propelled road vehicles had been operated with limited success even before the locomotive was perfected.

Experimental work of this nature was not confined to any one country, for the pioneers in the field included Nicholas Joseph Cugnot in France, Murdock, Symington, and Trevithick in England, and Oliver Evans in the United States. Cugnot built his car between the years 1763 and 1769. The boiler was so small it would operate only a few minutes at a time before it stopped until the pressure was built up again. Murdock's vehicle was a model employing atmospheric-pressure steam power, resulting in an engine too huge and cumbersome to be suited for self-propelled vehicles. Symington's carriage was also a model. Trevithick, who produced his first models of a portable high-pressure engine about 1796 or 1797, appears to be responsible for the mastery of high-pressure steam. His portable power unit was suitable for road vehicles. Trevithick built one and ran it on Christmas Eve, 1801. Evans was also a pioneer builder of high-pressure steam engines, primarily of the stationary type. A number of other inventors, including Anderson, James, Gurney, Hancock, and Macaroni, all built successful steam road vehicles Another invention of importance in automobile history during this period was that of the differential gear by Pacquer, a French watchmaker, in 1827.

Development of the internal-combustion engine. Soon after 1830, the interest of engineers and experimenters turned from the steam engine, which had reached a comparatively high degree of perfection in the steam locomotive, to the problem of the internal-combustion engine Their combined efforts reached fruition when a Frenchman, Lenoir, invented the gas engine in 1860.

Work on internal-combustion engines prior to Lenoir probably had little, if any, effect on their subsequent history. Lenoir modeled his engine after the steam engine, drawing in the gas-air mixture, then firing it and exhausting it on the return stroke. This cycle took place on both sides of the piston, and the engine was equipped with a crosshead, as in a steam engine. Another great step forward in the development of the internal-combustion engine was the 4-stroke cycle, in which the gas is compressed before ignition, thus greatly increasing the power of the engine. This 4-stroke cycle is commonly called the "Otto cycle," after Dr. Nathan Otto, who developed it in 1876, although Beau de Rochas claims to have proposed it first in a treatise published in France in 1862. This engine is the one most generally used in motor vehicles, especially in the United States, and, as such, is really the foundation of the entire automobile industry. Several important improvements to the Otto-cycle engine were added by Daimler and Maybach. Daimler was managing director of the firm of Otto and Langen and directed the building of the first 4-stroke-cycle gas engine. His contribution to the automobile engine was the development of a practical high-speed vertical engine. Maybach, Daimler's assistant, was responsible for the float-feed spray carburetor.

The first internal-combustion motorcar. In 1885, Carl Benz, a German, built the first internal-combustion engine to function practically, mounting it in a crude frame and driving it through the streets of Mannheim, Germany. Daimler, who had confined his attention after 1882 to producing a practical automobile engine, was not successful in his efforts to build an engine he considered satisfactory to mount in a 4-wheeled carriage until 1886. However, it was chiefly through Daimler's plodding, painstaking work that a gasoline engine was produced capable of displacing in a few years the already well-developed steam vehicle.

Levassor's contribution—construction principles and design. By 1889, when Daimler had completed his 2-cylinder engine, the steam car had been developed to a light, practical road vehicle capable of speeds of 25 to 30 miles an hour, the term "chauffeur" being originally applied to the stoker. Daimler's representative in France interested Emile Levassor, of the woodworking machinery firm of Panhard and Levassor, in the French rights for the Daimler engine. Levassor quickly recognized the necessity of building a car suitable for the engine rather than installing the engine in a carriage. He conceived the idea of a central frame to carry the power unit and to serve as the basis for the body and superstructure of the car. His contribution was of prime importance, for until that time, motor vehicles had been little more than carriages or buggies powered by a motor. This type of construction was correct when an animal was used to draw the vehicle, but it was definitely wrong when an internal-combustion engine was substituted as the source of power. In 1892, the firm of Panhard and Levassor issued the first automobile catalogue for a standardized car. The motor vehicle developed by this firm consisted of a regulation chassis frame, a running gear beneath the frame, and the two separated by elliptical springs, an engine

at the front end of the chassis, and the passenger body at the rear. Thus, the running gear, the power plant, and the body were separated so that each could be designed and constructed most efficiently. All subsequent motorcar design has followed this practice. Every important principle necessary to the satisfactory motor vehicle was applied in this car. There has been no essential change in the theory or practice of motorcar construction since, for none was necessary, although automotive engineers have made many improvements and refinements in the original design.

Advent of the rubber tire. Soon after the discovery of a process for vulcanizing rubber, it became possible to manufacture solid rubber tires for carriages. Early in the development of the automobile, the necessity

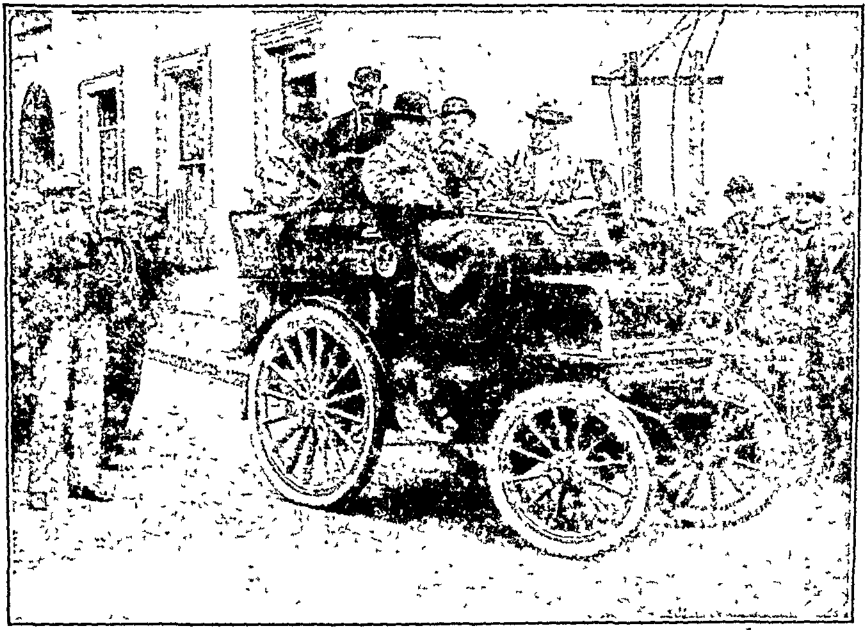


Fig. 1. First motorcar in Ireland.[2]

was recognized for some kind of tire that would not cut into the road and jar the machine as the iron-tired wheels did. The pneumatic tire had replaced the solid tire on bicycles largely through its superiority in bicycle races. Applied to the automobile, the pneumatic tire made for much greater riding comfort and eliminated the unpleasant bumping which had previously characterized all motor vehicles. The introduction of pneumatic tires and improved construction principles made possible the modern motorcar and prepared the way for the rapid expansion of ensuing years.

The automobile shown in Figure 1 is typical of the early European

[2] Occupants of car (left to right): Sir William Goff, W. Goff, Jr., J. G. Glover, Sr., W. Ogle, and Captain Roberts

car. It was the first car to appear in Ireland, June, 1900, and was driven by Sir William Goff some 50 miles, covered in 10 hours. This speed, however, had been greatly exceeded by earlier cars, the Paris-Bordeaux-Paris course in the 1894 races being covered at an average speed of 15½ miles per hour, while in 1899 a car built by Peugeot had attained a speed of more than 47 miles per hour.

Contribution of American engineers. European inventors and engineers had contributed the greater part of the development of the motorcar up to this point. The art was still in its infancy in the United States. Building the first American automobile required, not so much inventive genius, as the ability to incorporate into a motor vehicle the principles and ideas of European construction. Since that time, the industry in the United States has made some important contributions, chief among them being mass production and the continued program of constant improvement of existing models. Through engineering improvements and standardized manufacture, which reduced prices, the industry in this country has made it possible for persons even of moderate means to own and operate an automobile.

Early History of the Automobile in the United States

Early developments—steam cars versus gasoline cars. In the United States, the steam car developed much more rapidly at first than did the gasoline car. By 1900, it appeared as if steam were to be the dominant form of motive power for motor vehicles. However, the rapid improvement and use of the gasoline car in the years immediately thereafter soon turned the tide in favor of that type of automobile. The shift from steam to gasoline was brought about by the fact that the car using gasoline demanded less care and very little mechanical knowledge on the part of the operator. The low price of gasoline was an additional factor of considerable importance. A greater number of manufacturers of gasoline cars, together with aggressive advertising campaigns, also contributed to popularize this form of transportation. Hence, the market for steam cars gradually dwindled, until, by 1911, the Stanley was the only steam car being manufactured by an important company.

First successful American gasoline motor vehicle. Meanwhile, in 1892, Charles E. Duryea built the first successful gasoline motor vehicle in this country. The next year, Henry Ford and Ransom E. Olds constructed and ran gasoline motorcars of their own design. In 1894, Elwood Haynes and the Apperson Brothers also built successful motorcars. Increasing numbers of experimental vehicles appeared on the roads and highways during the last years of the century.

Approximately 300 cars were manufactured in this country between 1886 and 1898, the majority electric and steam. Yet even in the latter year, the automobile industry was not separately classified in the Census. It was just on the eve of its rapid development. Sales of gasoline cars were few and scattered. Even in 1900, when Olds had come into production and built more than 400 cars, the total output of vehicles for the year consisted of 1,681 steam, 1575 electric, and 936 gasoline cars.

TABLE I

PRODUCTION OF AUTOMOBILES IN THE UNITED STATES

Figures for 1921 to date are "factory sales" for United States plants and "production" for Canadian.

Foreign assemblies of parts manufactured in the United States are included in this table as well as in the monthly figures compiled by the United States Census Bureau.

Year	*Population*	*Total Cars and Trucks*	
		Number	*Value*
1900[a]	75,994,575	4,192	$4,899,443
1901	77,747,402[c]	7,000	8,183,000
1902	79,365,396[c]	9,000	10,395,000
1903	80,983,390[c]	11,235	13,000,000
1904[a]	82,601,384[c]	22,830	24,629,439
1905	84,219,378[c]	25,000	40,000,000
1906	85,837,372[c]	34,000	62,900,000
1907	87,455,366[c]	44,000	93,400,000
1908	89,073,360[c]	65,000	137,800,000
1909[a]	90,691,354[c]	130,986	165,148,529
1910	91,972,266	187,000	225,000,000
1911	93,682,189[c]	210,000	216,000,000
1912	95,097,298[c]	378,000	378,000,000
1913	96,512,407[c]	485,000	443,902,000
1914[a]	97,927,516[c]	569,054	458,957,843
1915	99,342,625[c]	969,930	701,778,000
1916	100,757,755[c]	1,617,708	1,082,378,000
1917	102,172,845[c]	1,873,949	1,274,488,419
1918	103,587,955[c]	1,170,686	1,236,106,917
1919	105,003,065[c]	1,933,595	1,885,112,546
1920	105,710,620	2,227,349	2,232,420,373
1921[b]	108,207,853[c]	1,682,365	1,261,666,550
1922[b]	109,872,675[c]	2,646,229	1,793,022,708
1923[b]	111,537,497[c]	4,180,450	2,592,033,428
1924[b]	113,202,319[c]	3,737,786	2,367,413,015
1925[b]	114,867,141[c]	4,427,800	3,015,163,562
1926[b]	116,531,963[c]	4,505,661	3,211,817,491
1927[b]	118,196,785[c]	3,580,380	2,700,705,743
1928[b]	119,861,607[c]	4,601,141	3,162,798,880
1929[b]	121,526,429[c]	5,621,715	3,576,645,881
1930[b]	122,775,046	3,510,178	2,128,792,145
1931[b]	124,070,000[c]	2,472,359	1,901,586,000
1932[b]	125,000,000[d]	1,431,544	1,047,307,000
1933[b]	125,770,000[d]	1,985,909	987,436,289
1934[b]	126,626,000[d]	2,869,963	1,537,290,336
1935[b]	127,521,000[d]	4,119,811	2,187,816,702
1936[b]	128,429,000[d]	4,616,274	2,574,421,895
1937[b]	129,257,000[d]	5,016,437	2,971,027,641
1938[b]	130,215,000[d]	2,655,171	1,717,150,414
1939[b]	131,000,000[d]	3,732,718[d]	2,418,030,606[d]
1940	131,669,275[d]	4,469,354	3,012,100,000

[a] From United States Census reports for fiscal year ended June 30, 1900.
[b] Figures include production of plants located in Canada
[c] Estimated figures, from *Statistical Abstract of the United States* (1939), Table No. 12, page 10
[d] Estimated.

First approach toward mass production. It should be understood, of course, that these early cars were not "manufactured" in the modern sense of the word. Rather, they were elaborately, albeit crudely, built by hand with such tools as were available. The first instance of anything approaching mass production occurred in 1898, when the Mitchell-Lewis Motor Car Company of Racine, Wisconsin, manufactured 500 3-wheeled motor vehicles for the European market. The next year, Amzi L Barber, an asphalt manufacturer, purchased the interest of the Stanley Brothers, two pioneers in steam cars, and formed the Locomobile Company of America. The second year he was in business, Barber manufactured and sold more than 1,000 cars.

The Olds Motor Works produced 400 cars on a commercial scale in 1901 and nearly 4,000 cars in 1903, before deserting the low-priced field. The Cadillac Company also pushed to the front of the field, achieving at this time an output of 30 to 40 cars a day. The Ford Motor Company was founded in 1903 and, by 1907, was beginning to think in terms of "mass production," as compared with the output of automobile factories up to that time. Inefficiencies in factory methods were eliminated; new labor-saving devices were introduced. The whole tempo of the industry began to be speeded up. Ford succeeded in manufacturing 10,000 cars in 1908, and other companies were not far behind in seeking to duplicate this feat. The result is that automobile production has risen progressively since that time, with only periodic interruptions, as will be seen from Table I, giving production figures for the period from 1900 to 1940.

Automobile Mass Production

The principle of division of labor. To understand this tremendous production of the modern automobile factory, it is first of all essential to realize that probably nowhere else has the principle of the division of labor been carried further. Each worker does just that bit of work for which he is particularly qualified. Thus, there is no waste energy, no waste motion. The modern automobile is made up of approximately 15,000 parts, which must be designed, manufactured, and assembled. After the tremendously important contributions of the engineers, designers, and other technicians have been made, thought and skill, to a marked extent, are transferred from the worker to the machine, since practically all of the construction of the parts of a motorcar, and some of the assembly are done automatically by machine, only tended and watched over by the men in charge. The men employed as inspectors, welders, tool-and-die makers, skilled maintenance men, and metal finishing workers comprise more than one fourth of the total personnel of automobile and automobile-parts plants. Thus, through the application of the principle of division of labor, the industry has made continuous progress toward a better product at lower cost.

Factors responsible for mass production. The evolution of the present system of mass production is worthy of the keenest study, for it is

undoubtedly one of the notable examples of American genius and efficiency.

American manufacturers began early to specialize in production of cars with interchangeable parts—that is, each manufacturer built cars so that parts made for any one car would fit all the others of that particular model. This fact was graphically illustrated when Henry M Leland took three American cars to England in 1903, drove them around the Brooklands race track, took them apart, substituted 91 stock parts taken indiscriminately from the cars, and then reassembled three complete machines from the confused pile of parts.

Some years later, Henry Ford gave further impetus to this practice when he decided upon his universal model T, which was to follow the theory of interchangeable parts to its final conclusion. For in Ford's plans, the car was to be always of one color—black—and so standardized that owners could keep their machine up to date merely by purchasing and adding new improvements as they were developed from time to time at the factory. Even more important, perhaps, was Ford's determination to have the various parts of his car made so accurately that there would be no necessity to make the slightest adjustment when the car was being assembled. Each part was to fit snugly and smoothly into its appointed place in the machine.

This kind of manufacturing, commonplace as it is today, was a bolt out of the blue when Ford propounded it to a startled automobile industry in 1907. Speaking of Ford's plans and how effectively they worked out in actual practice, the *Cycle and Automobile Trade Journal* accurately said:

> The utmost care was taken to have the parts of the car absolutely machined to size. No supplementary fitting was possible in the scheme. Every part must go into place without causing a moment's delay in the assembly room.
>
> The manufacturing world stood aghast. Only very few believed Ford would progress far with so radical a departure. But he did . . . and the principles laid down in Henry Ford's general scheme are substantially those that prevail in the industry today.

The principle of standardization. While individual manufacturers advanced from the stage of hand fabrication to a system of interchangeable parts in their cars, there nevertheless remained a wide divergence between the individual requirements of different companies with respect to parts and accessories. For example, in 1911, one company manufacuring lock washers for the industry was compelled to supply 800 different sizes of such washers to be used with bolts having a diameter varying between three sixteenths and one half of an inch. So different were the various demands of the industry that, altogether, 1,600 sizes of steel tubing and 135 different grades of steel were being specified by the manufacturers. The folly of this practice, which could easily be eliminated by having certain standard sizes for various components of every motorcar, gradually became apparent, largely through the work of the Society of Automotive Engineers. Founded in 1904, with only four members at the first meeting, the society has filled a definite need in the automobile

industry and is today the leading technical organization of the industry. The formation of its Standards Committee in 1910 definitely pointed the way to simplification of engineering practice, while not impeding the expression of justified individualism in construction or design of motor-cars.

Wheel sizes, tire fastenings, cotter-pin sizes, spark-plug sizes, axles, valve seatings, screws, lock washers, spring parts, bearing parts, and a host of other minor parts have all been standardized to a great extent. Standardization has affected mass production, in turn, by lessening the price of parts going into the car and hence enlarging the potential market for the automobile industry.

Reorganization of the Ford plant. Ford's introduction of a universal model and interchangeable parts made it possible for Walter E. Flanders, who became Ford's production manager in 1908, to effect numerous improvements in attempting to step up the plant's capacity to produce 10,000 cars a year. Flanders immediately reorganized the entire Ford factory. He adapted many of the existing machine tools to the new models he was to produce; he manufactured jigs, fixtures, dies, and templates for other parts; and finally he supervised the quality of materials going into the cars. It was through such methods that the Ford factory, under Flanders' management, achieved the notable record of producing 10,000 cars in one year—an unprecedented achievement at that time in the history of the automobile industry.

Flanders' contribution to the industry. Flanders soon left the Ford company to join B. F. Everitt and William E. Metzger in forming the E-M-F Company to manufacture a car known as the "E-M-F 30," which was important because it was a "jig job"—that is, each part on which a mechanical operation was to be performed was brought to that operation tightly clamped into a frame corresponding in its dimensions to the base of the tool which was to perform the operation. The use of these mechanical aids in manufacture resulted in a degree of accuracy and uniformity of production that would otherwise have been impossible Flanders also contributed materially to automotive production by developing and perfecting automatic machinery which had been almost neglected. For example, he produced millers which simultaneously smoothed two or more faces of a casting and developed automatic screw machines, gear cutters, and die presses. In short, he applied to the production of automobiles practices and methods which had been in use for some time in the production of other machines, such as sewing machines, bicycles, and harvesters.

Automobile production. These and other improvements gradually prepared the way for the manufacturing methods of the modern automobile factory, which may be briefly described. There are really three steps in automobile production: (1) the raw materials are made into parts; (2) the parts are combined into nine primary units; (3) the units in turn are assembled into the complete car. In many instances, whole factories are given over to the manufacture of parts, which can then be

shipped to branch assembly plants throughout the country, thus effecting considerable savings in transportation costs.

Manufacturing parts. The usual automobile factory manufacturing parts is grouped into numerous departments, each of which handles a single part, transforming it from the original crude form into a finished product. Thus, a rough forging or casting will emerge as a finished part, ready to be combined with other parts into a unit.

Primary assemblies. After they have been completed and inspected, these parts are either shipped to distant assembly plants or carried by belts or overhead conveyors to points within the same factory to be assembled into the primary units of the car, such as the motor, radiator, dash (including the wheel), frame, body, gas tank, wheels, and the front and rear axles.

Final assembly—the assembly line. These primary units, in turn, are taken by various automatic carriers to the main assembly line to be built with amazing swiftness and dexterity into completed motor vehicles The assembly line itself, which is particularly distinctive of the automobile industry and exemplifies a principle which is now in general application throughout most manufacturing industries, is a moving platform about 18 inches high upon which the automobile is gradually built up. The assembly line is usually electrically operated. Assembly of the car begins when the frame is placed on the line in an inverted position. As the frame moves along, at the rate of approximately 18 feet per minute, various units and subassemblies are quickly added.

Each man along the line has one or more specific operations to perform on each automobile, and all material used in the assembly is either held in quantity at the point on the line where it is being used or is delivered there by overhead conveyors.

The first units added to the frame are the rear and front springs. They are followed by the rear-axle assembly, complete with brake equipment and next the shock absorbers. At this point, the frame and auxiliary equipment, which have been in an inverted position, are turned upright. Parts now added in order are the hydraulic brake tubing, sway eliminator, propeller shaft, muffler assembly and gas tank, and the engine which is received from the motor assembly line.

Importance of inspection. To insure accuracy, following practically each operation, every part is inspected and checked with infinite care, so that there is little possibility of its exceeding the allowable limit of error. In the modern motorcar factory, several thousand dimensions of different parts must check within one one thousandth of an inch of the prescribed size, or within the smallest fraction of an ounce in weight. There are some inspections, made with the aid of the most delicate micrometers, for one tenth of one thousandth of an inch. Only in this way is it possible to make sure that the complete car will prove as satisfactory and as smooth in performance as it is designed to do.

Motor assembly. A complete and subordinate assembly process, also of vital interest because of its importance, has meanwhile been going on in another part of the factory, leading to the assembly of complete engine

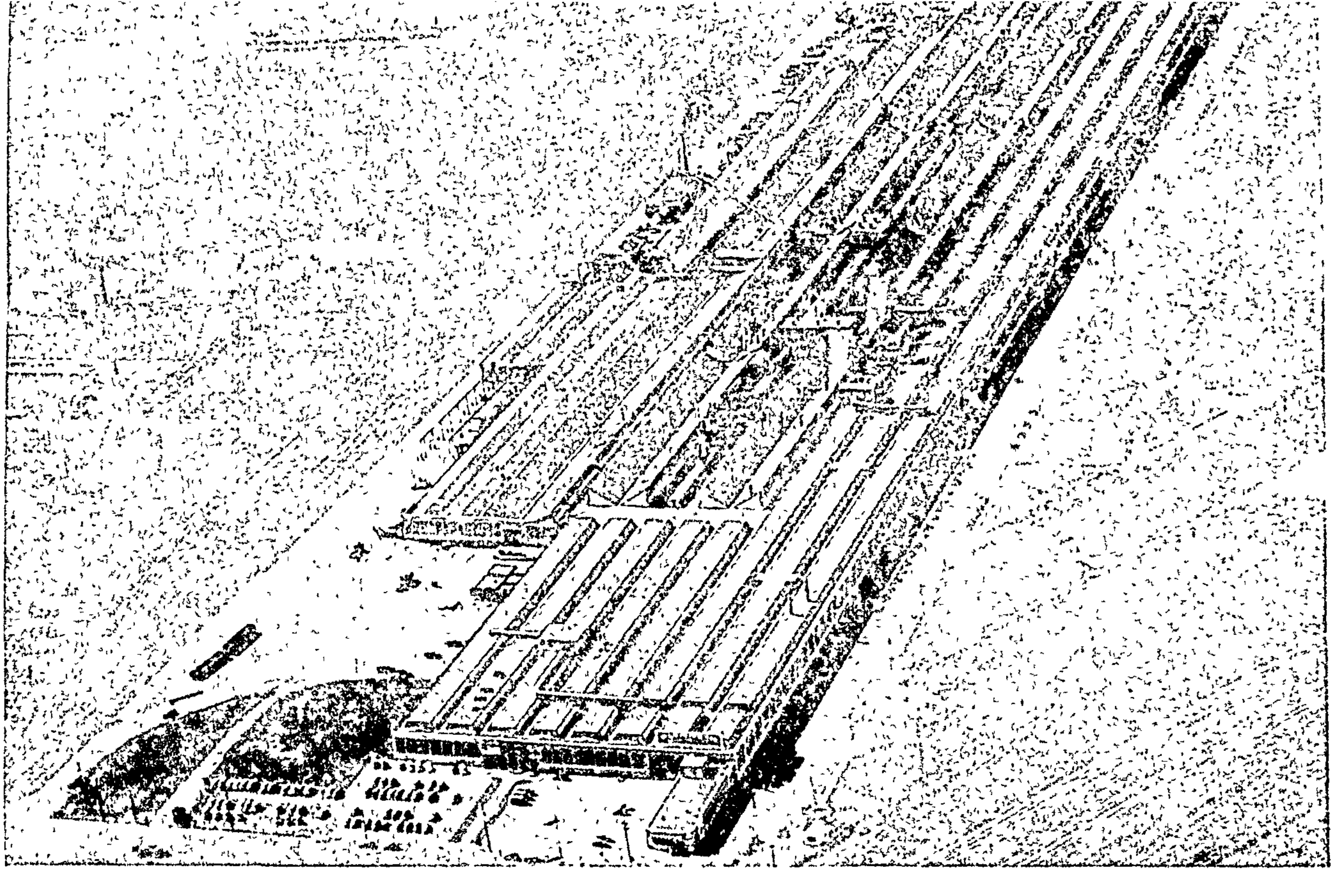


Fig. 2. Plymouth plant of Chrysler Motor Company at Detroit, Michigan, contains largest assembly line in the world; at full capacity it can turn out 3 cars per minute.

units. First of all, the motor blocks are brought to the assembly conveyor, already assembled with valve mechanism, pistons, connecting rods, and the upper halves of the main bearings. The pistons are carefully selected and matched. In the Plymouth, for example, a variation of only two hundredths of 1 pound is allowed in an entire set. The same care is used in matching up the connecting rod sets, with an equally small limit of error.

On the assembly line, the motor takes shape very rapidly. The block goes on the line in an inverted position, thus permitting access to the engine interior. Then the crankshaft, flywheel, and clutch assembly are installed and the crankshaft bearings tightened. Each shaft must be absolutely balanced at rest as well as in rotation.

After the crankshaft has been installed, the connecting rods are connected and the bearing caps put in place. Then the oil pump and oil lines to the pump are installed, the flywheel housing is added, and the timing-gear case is put on. After the oil pan has been added, the motor is turned over, bringing it to an upright position, and the cylinder head is then installed. The spark plugs are inserted, the transmission, brake, and clutch parts are put in place, as well as the manifolds, fan, electrical equipment, and carburetor. Then, after the carburetor has been installed, the engine number is stamped into the block, the oil caps are put in place, grease is forced into the transmission, and the engine is finished and ready for the testing room.

Today's motorcars are designed to perform so notably and with such precision that constant testing is necessary during the construction process to make sure that they are capable of performing the feats claimed for them. In the Chrysler factories, and it is true of practically every automobile manufacturer, the finished engines are transferred from the assembly line over to what is known as the "testing line" and carried down to the testing section, where overhead hoists are used to transfer them from the line to the running-in stands. During this entire time, it is being carefully inspected by several skilled mechanics to see that every part is working properly and that the engine "sounds" right

It is of interest to note that, while they are on the stands for this testing period, the motors are fueled with regular illuminating gas, which is mixed with a large amount of air to make it highly combustible. At the conclusion of the 2-hour period, the engine is put back on the engine-assembly line and carried around to the dynamometer-test room. Here each engine must show the normal horsepower expected of it, or it is rejected. In order that the test on the dynamometer may be based on normal operating conditions, gasoline is used as fuel and is put through the engine's own carburetor.

When it has satisfactorily passed all these various tests, the engine goes to the overhead platform over the main assembly line, where it is lowered through a hatchway to the waiting chassis and mounted there.

Completing assembly of the car. With the engine installed, the chassis passes into a booth where it is enameled. High-pressure spray guns are used to insure an even application of enamel to all parts. Cylin-

der head, carburetor, and other parts not to be enameled are carefully protected by masks during the spraying. From the enameling booth, the chassis passes into an overhead, electrically heated oven for drying.

After the chassis emerges completely dry and with the brilliant luster which is such a distinctive feature of today's automobiles, the speed of assembly appears to be heightened, largely because exterior parts like the wheels, with tires mounted and already inflated, are added, as are also the air cleaner, steering-gear assembly, rear bumper and rubber body mountings.

In the meantime, the body has been received on another assembly line. As the body moves along, the dash is installed, the windshield wipers are added, and the body is wired. The instrument panel is put in place, and added, in order, are the fender welts, rear fenders, glove box, body hardware, radiator case, front fenders, horn, battery, and head lamps.

The chassis is now ready for the body, which is picked up from the body-conditioning line by an overhead cabin hoist and brought to the main assembly line. Persons witnessing the assembly process for the first time are often led to comment upon the dexterity and precision with which the hoist operator maneuvers the body and allows it to come into position on the chassis. With the body in place, the body bolts are tightened; the instruments are connected to the engine; the running boards, or body side shields, are added; the front bumper is installed; and the steering wheel, hood hinges, floor covering, and one-piece hood top are put in place. Gasoline and water are now poured in, the headlights are aimed, and the car runs off the line under its own power.

One other set of rigorous tests still remains to eliminate all possible error and to make sure that each car is mechanically perfect. Going to the test stands, the completed cars are checked with respect to every phase of their operation, including the performance of carburetor, brakes. transmission, and clutch. From the test stand, the cars go to a final inspection line to receive a thorough and searching inspection that includes all equipment, doors, locks, hinges, window mechanism, exterior finish, interior trim, lights, and starter. Once they have passed this final test, the cars are ready for immediate delivery or for shipment to dealers in all parts of the world

Production control. The guiding principle of motorcar production is to save time by bringing the material to the worker and not having the worker go to the material, as was formerly the case. Moreover, each man or group of men performs a special function on each car. This eliminates delay which might otherwise develop as a result of the worker's lack of familiarity with what he is doing. The men are able to become remarkably proficient in the various operations they perform.

So efficient has the entire organization of automobile production become that, within 14 days from the time raw material is purchased, a completed car built of this steel and rubber runs "off the line" under its own power. For the achievement of this degree of perfection, a vast amount of thought and planning must go into the design and operation of the

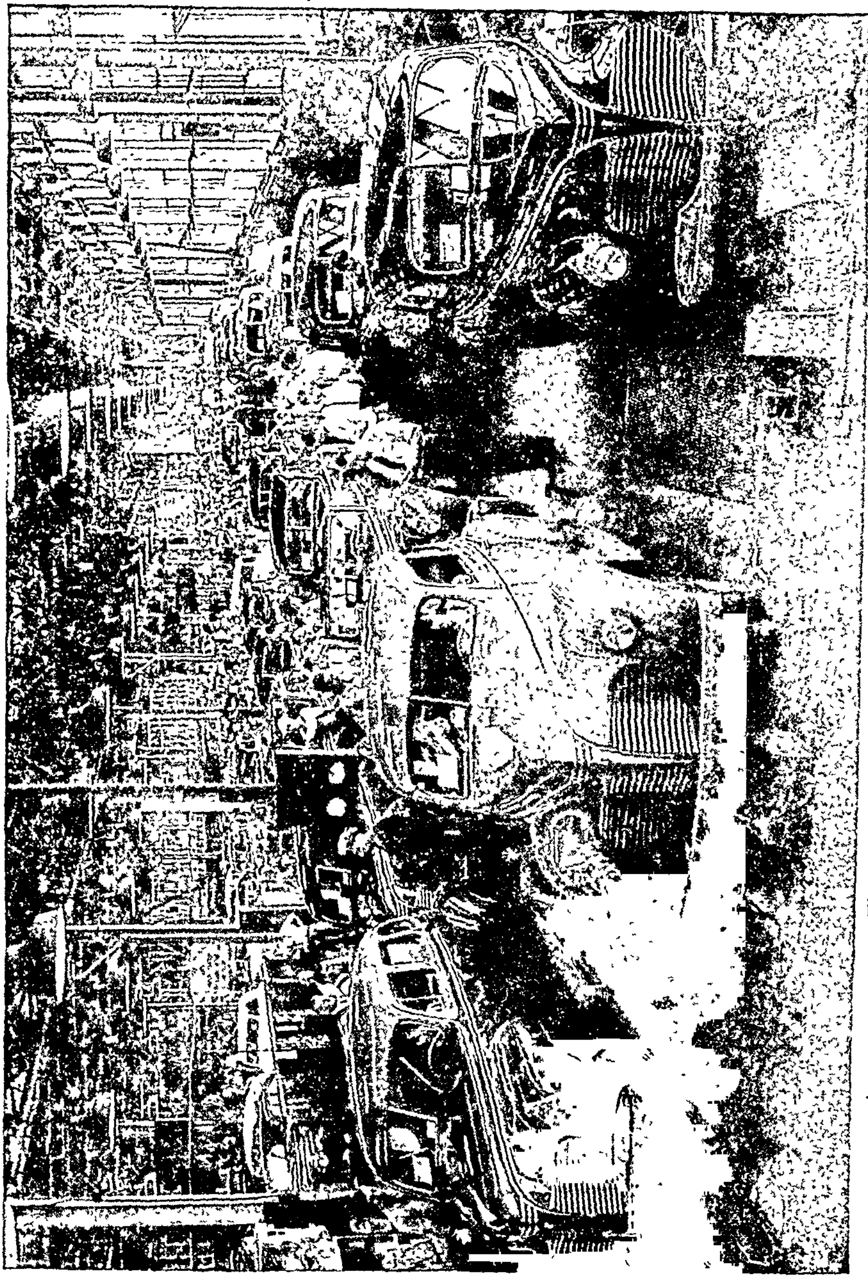


Fig. 3 Assembly line in Plymouth plant in Detroit.

modern factory. If confusion and chaos are to be avoided, it is absolutely necessary that the arrangement of machinery and the movement of materials be planned with great exactness. Delay in obtaining a supply of any of the hundreds of parts entering into the manufacture of a car of necessity holds up the entire production organization, with appalling loss of time and money.

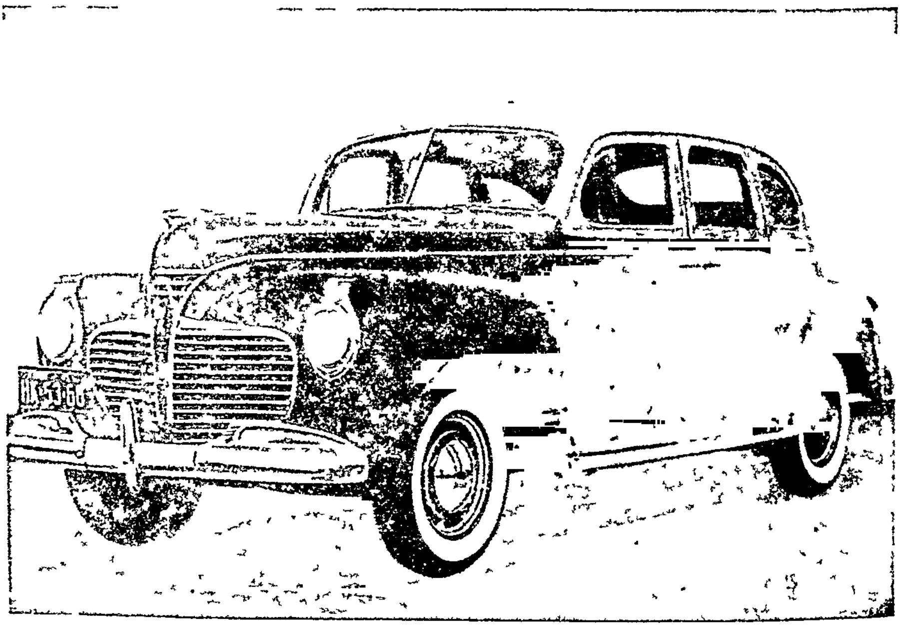


Fig 4 Plymouth special de luxe 4-door sedan

Integration

There was a time in the industry when each company sought to become completely self-sufficient, in order to insure a constant flow of parts and materials Contributing to the same result, also, was the desire to avoid paying a profit to manufacturers of parts and accessories Thus, one large company acquired forests in Michigan, coal fields in West Virginia, and an entire railroad to transport to its factories the products of mine and field which enter into the modern motorcar. Similarly, another outstanding unit in the industry achieved possibly an even greater degree of integration by merging with itself a large number of accessory and parts companies, so that now, in reality, its entire motorcar output is the product of its own organization.

Since 1927, however, there has been a tendency on the part of some companies to confine their activities solely to building their own engines and to assembling their output from parts supplied by outside agencies, under contract. This change in practice can be explained in part by the fact that, as manufacturers shift from model to model, they are com-

pelled to bear considerable expense for altering even the assembly facilities of their factories. If to this is added the cost of retooling an entire plant which manufactures parts, the expense becomes almost prohibitive. It is these factors, chiefly, which have tended to lessen enthusiasm for controlling the entire production of motorcars, from raw materials to finished automobiles, within a single organization.

The Patent Situation

Comparative freedom from restrictive effects of patents and patent litigations. It is a notable concomitant of the growth of the automobile industry in this country that the automotive art has been remarkably free from the restrictive effects of patents and patent litigation. The reasons for this are several. In the first place, the American industry did not begin until after about 100 years of development in Europe. The Trevithick vehicle of 1801 is considered to be the first practical automotive vehicle. From that time on, a great many vehicles were made and a great deal of experience was gained. In the second place, the only patents based on European development to bother the American industry would be patents that would still be in effect when the American industry began around 1900. It is true there were a number of inventions patented in Europe that might have been covered by patents in this country which would still have been effective in 1900, but these patents were not taken out in this country.

The chief exception to the small number of patents granted against the automobile industry was that of George B. Selden of Rochester, New York, applied for in 1879 and allowed to linger in the patent office until the industry was on the eve of a great development in 1895. This patent was understood to cover the use of an internal-combustion engine to propel a road vehicle. Practically all important manufacturers in this country joined the Association of Licensed Automobile Manufacturers and paid royalties from 1903 to 1911 for the right to use Selden's principle in their cars. In the latter year, however, the courts ruled that Ford, who had fought the patent, had not infringed upon it, since he, together with most motorcar companies, was using an engine of the so-called "Otto type," while Selden had based his patent application on what is known as the "Brayton engine." Members of the association immediately ceased paying royalties, and the association was dissolved. Its place was taken by the Automobile Board of Trade, which in turn was succeeded, in 1913, by the National Automobile Chamber of Commerce. In 1934, the name of this organization was changed to the Automobile Manufacturers Association, the trade organization of the industry at the present time.

Reciprocal interchange of patents. The danger of expensive litigation over such automotive patents as are in effect has been eliminated, since 1915, by a cross-licensing arrangement. In effect, this constituted nothing more than a reciprocal interchange of patents among the members, without money consideration. The agreement of 1915 was for a 10-year

period. It was renewed in 1925, in 1930, and again in 1935 for additional 5-year periods. The agreement covers more than 1,000 separate patents relating to all parts of the motorcar. During the 25 years it has been in effect, there has not been a single patent suit between members regarding any patent covered by the agreement. However, to encourage engineering progress and individuality, the arrangement provides that external body shapes and other "design patents," and also patents applying to commercial motor vehicles, are not within its jurisdiction.

In the third renewal of the agreement, in 1935, it was agreed that only patents obtained before 1930 should be included under its terms and, in addition, exempted patents developed by a corporation or division not engaged in building complete motor vehicles. This change was made because of the fact that several units in the industry spend such large amounts in automotive research and development that it would be unfair to them to make new patents immediately available to the entire industry without remuneration.

The benefits of the cross-licensing pool are of great importance to the industry. Primarily, it has reduced the price of motorcars materially by eliminating practically all costs for royalties, which otherwise would have been paid by the various manufacturers and, indirectly, by the public.

Geographic Concentration of the Industry

Early in its history, automobile production in the United States tended to become localized in a small number of centers, particularly in Michigan and Ohio. One of the chief reasons for the emergence of Michigan, and particularly the area around Detroit, as a manufacturing center is to be found in the number of early leaders in the industry who lived there: Henry Ford, Ransom E. Olds, David Buick, Charles King, Henry M. Leland, and others. Similarly, Ohio was the home of Alexander Winton, the White family, and the Peerless group. It was natural and fitting that these men should establish their factories at home and begin their production of automobiles there.

Moreover, Michigan had early become the scene of extensive iron and copper mining. The presence of these industries, together with the great timber supplies available there, encouraged the establishment of a wide variety of enterprises, including such divergent interests as shipbuilding, carriage-and-wagon manufacture, and the production of steam and gasoline engines for stationary use. Onio likewise had become a prominent industrial region, especially in steel production and the bicycle industry. There were thus at hand a large number of men fitted by nature and experience to participate in the development of the new industry.

Automobile production also tended to become concentrated because of the marked success of the early manufacturers in the two states already named. By 1907, Buick, Ford, Olds, Cadillac, Packard, and numerous other companies in the vicinity of Detroit were achieving notable records, which tended to draw other companies to the same locality. The pres-

ence of automobile manufacturing soon led to the development of a body of workmen skilled in the automotive art and available for new enterprises.

Even more important, perhaps, bankers in the Middle West, particularly Detroit, were early convinced of the possibilities of the motorcar industry. Hence, they were more willing to extend financial accommodation than were the bankers in large Eastern cities. All these influences combined to establish the automobile business as an almost local industry, and intervening years have done little to change the situation, except as branch assembly plants have been placed in various parts of the country to save transportation costs.

Financing the Industry

Early growth retarded by lack of capital. Early growth of the various automobile companies was retarded somewhat by lack of capital funds. The Ford Motor Company started with a capital of $28,000; the Hudson Motor Car Company and others, with even smaller amounts. Consequently, they were compelled to build up their capital funds as they went along, largely out of earnings, which were immediately plowed back into the enterprise. Thus, even today, the industry is remarkably free of fixed obligations, and capitalization consists largely of stock issues. With the exception of Dodge Brothers, no company became a large producer during its first year in the business. Public confidence was not sufficient to make it possible to distribute securities of the industry until it became more stabilized. Hence, many companies struggled along by obtaining parts on 60- to 90-day credit terms, by charging the distributor a deposit of as much as 20 per cent of the total value of the car when he placed his order, and by requiring full payment for the car upon delivery. In this way, it was possible to meet the parts-manufacturers' bills as they became due and to pay the employees. A surplus was gradually built up to insure the company's future and to provide for plant expansion as it became necessary. The demand for automobiles, for many years exceeding the available supply, made such hand-to-mouth financing possible. Yet, even under these circumstances, the passage of the years, the panic of 1907, and many other untoward events took a heavy toll of the companies in the industry.

Automobile securities. It was not until 1910, when the General Motors Company offered an issue of 5-year notes, that the first automobile securities were publicly distributed. That same year investment bankers organized the United States Motor Company, offering its stock to the general public. In 1911, Studebaker Brothers Manufacturing Company, reincorporated as the Studebaker Corporation, absorbed the Everitt-Metzger-Flanders Company and issued $13,500,000 par value of 7 per cent preferred stock Shortly afterward, securities of General Motors, Maxwell, and Studebaker were listed on the New York Stock Exchange. The Willys-Overland Company sold issues of common and preferred stock in 1915 to acquire a number of smaller units in the indus-

try. Also, the Chevrolet Motor Company, soon to obtain control of General Motors, successfully sold about $7,000,000 of common stock in the same year. This step may be said to mark the end of the second period in automobile-company finance. In the intervening years, credit of automobile manufacturers has greatly improved. Stocks of practically all motor companies have been listed on leading exchanges, additional shares have been sold to the public, and "rights" to take up new issues at a concession have been offered to stockholders. The years since 1915 have also witnessed the association of investment bankers with the various companies and the placing of their representatives on the respective boards of directors.

Leading Companies in the Industry

Because of the tremendous savings made possible by large-scale operations, motorcar production in this country has been concentrated to the extent that it is now in the hands of relatively few companies. Since practically all patents are interchanged without financial remuneration, most manufacturers have no competitive advantage in this respect and must depend for success solely upon the value of their product. Hence competition between various units is unusually keen and effective. Leadership can be attained only through sheer merit.

Reference has already been made to the high mortality among motorcar companies. According to studies made by Dr. Ralph C. Epstein, 181 different companies engaged in the manufacture of passenger cars from 1903 to 1926, inclusive. Of this number, 137 retired from the field, leaving only 44 passenger-car manufacturers at the end of the period. It is noteworthy, also, that only 11 automobile manufacturers were in business during the entire period.

In recent years, three companies have accounted for about 90 per cent of the total passenger-car production in the United States, with about a dozen other companies competing for the remaining 10 per cent of the business. Domestic sales of the leading companies are shown in the following table, covering the period from 1934 through 1939:

Success in the automobile industry has largely depended upon the ability of individual producers to anticipate what the public desires in motorcar performance and design. In the industry's formative period, when demand far exceeded available production, motorcar performance was deemed more important than design. Comparatively little attention was given to the beauty of a car, provided it ran successfully and afforded the owner satisfactory service. The early motorcar companies, with one or two notable exceptions, achieved leadership by producing a serviceable car for the person of average means. More recently, however, because of the generally high standard of motorcar performance, the public has come to consider such additional qualities as speed, style, beauty, and economy of operation when purchasing an automobile.

Thus, the automobile industry in the United States has already passed through two eras, that of the "assembled car" and that of the "engi-

neered car." It is now entering upon a third era, that of the "scientific car," in which the automobile calls upon pure science for the improvements it offers the public. It has been the privilege of the Chrysler Corporation, through establishing design and construction on sound engineering principles, to take a prominent part in making the automobile a thing of beauty as well as a serviceable and dependable transportation vehicle. No longer is an automobile merely a power plant combined with a buggy. Today, it is a self-contained unit, designed and constructed from top to bottom to conform to known needs and requirements. Improvements have been made as the result of study, not only of the automobile, but also of the fundamental laws of nature and requirements of the human body, and then by adapting the car to the functions of both. Similarly, engine design has been improved to such an extent that the modern passenger car is characterized fully as much by its speed and performance as by its trim appearance. The distinguishing features of the automobile of today are beauty, comfort, safety, and efficiency.

TABLE II

NEW PASSENGER-CAR REGISTRATIONS BY MAKES FROM 1934 TO 1939

Manufacturer	*1934*	*1935*	*1936*	*1937*	*1938*	*1939*
General Motors Corporation	752,375	1,052,297	1,466,852	1,414,186	847,885	1,158,871
Chrysler Corporation	432,195	629,243	851,884	883,572	472,565	641,299
Ford Motor Company	532,589	828,889	764,121	791,176	387,514	567,320
Graham	12,887	15,965	16,439	13,984	4,139	3,660
Hudson	59,817	75,425	99,296	90,043	40,889	62,855
Hupmobile	6,566	7,450	1,556	403	1,020	907
Nash	23,616	35,184	43,070	70,571	31,814	54,050
Packard	6,552	37,653	68,772	95,455	49,163	62,005
Studebaker	41,560	39,573	67,835	70,048	41,504	84,660
Willys	6,576	10,439	12,423	51,411	13,012	14,734
Miscellaneous	13,824	11,790	12,249	2,903	1,516	3,016
Total	1,888,557	2,743,908	3,404,497	3,483,752	1,891,021	2,653,377

Simultaneously, the benefits of modern production methods and improved manufacturing technique have gradually made it possible for the producer to diminish the cost of his product to the public. Notwithstanding the marked improvements of recent years in automotive design and performance, prices have constantly been lowered as conditions warranted. As a natural consequence of this wise policy, the public now obtains unprecedented values in motor-vehicle transportation. Although the modern automobile is vastly superior to the vehicle of 1925, the average retail price of cars has decreased some 24 per cent, or by almost one fourth, since 1925. The cost per pound of the 1939 model was but

$.263, as compared with a cost for the 1925 car of $.427 per pound. The cost per horsepower in 1939 was $9.10, as compared with $31.50 in 1925. Put in another way, the automobile dollar in 1939 was worth $1.24, as compared with 1925; whereas, according to figures compiled by the United States Bureau of Labor Statistics, the urban cost-of-living dollar in 1939 was worth but $.82, as compared with that of the period 1923 to 1925.

Since the early days of the automobile, companies manufacturing a good low-priced car have enjoyed a large measure of success. The market for low-priced cars has steadily increased, until, in 1939, almost 90 per cent of all passenger automobiles produced in the United States were priced, wholesale, at $750 or under. The trend in recent years toward a reduction in output of higher-priced cars and an increase in that of lower-priced cars is indicated by the following compilation:

Table III

PASSENGER-CAR PRODUCTION BY WHOLESALE PRICE CLASSES FOR THE UNITED STATES AND CANADA

Year	*Cars Priced Under $1,001*		*Cars Priced at $1,001 to $2,000*		*Cars Priced at $2,001 to $3,000*		*Cars Priced Over $3,000*	
	Number	*Per Cent of Total*	*Number*	*Per Cent of Total*	*Number*	*Per Cent of Total*	*Number*	*Per Cent of Total*
1926	3,283,584	83.2%	571,590	11.5%	73,738	1.8%	19,931	.5%
1927	2,443,866	79.3	574,327	18.7	50,064	1.6	15,103	.4
1928	3,380,321	84.2	561,565	14.1	55,301	1.4	11,968	.3
1929	4,290,365	89.5	445,426	9.3	47,587	1.0	11,520	.2
1930	2,639,519	90.8	234,531	8.1	27,266	.9	8,841	.2
1931	1,905,177	93.5	114,533	5.6	12,714	.6	5,759	.3
1932	1,129,605	95.3	45,369	3.8	8,679	.7	2,532	.2
1933	1,586,050	97.5	30,534	1.9	8,725	.5	2,052	.1
1934	2,225,569	98.0	35,967	1.6	6,879	.3	2,151	.1
1935	3,342,513	98.6	37,452	1.17	5,413	.16	2,428	.07
1936	3,740,445	98.5	51,512	1.35	4,326	.11	1,584	.04
1937	4,020,713	98.8	42,859	1.08	4,061	.09	1,302	.03
1938	2,076,101	97.7	45,821	2.17	2,161	.10	663	.03
1939	2,919,614	98.1	53,337	1.79	1,870	.06	344	.01

These revealing figures lead students of automobile history to believe that the future of any motor company will depend in large measure upon the success which it meets in the low-priced field, since it is expected that dominance in the industry will continue to go to the companies producing the most satisfactory and desirable car priced under $1,000. Consequently, it is believed that competition in the low-priced field will remain exceedingly keen, with accompanying benefits to the public.

Automobile Marketing

Methods of marketing. The automobile market has been nationwide almost from the beginning, whereas production has been centralized. Consequently, actual distribution of the cars from manufacturer to purchaser was naturally effected through third parties, or dealers. With the development of the industry, wholesalers were frequently placed in charge of dealers in extensive territories, sometimes including two or more states, to act as an additional link between the factory and the individual customer and to insure a closely knit system of distribution. From time to time, too, practically all companies have tried the expedient of establishing their own branches to distribute cars to the public, and this method has met with varying success, since it depends for its effectiveness upon the personnel in charge of the branches and also upon the location of the branch.

Principles governing sales. Distribution of automobiles through retail merchants or dealers, as distinguished from distribution through branches maintained by the manufacturer, is characterized by four basic principles. The first of these is that cars are sold, not on consignment, but outright. Second, all factory sales are for cash. Third, wholesale distributors are almost always expected also to sell at retail. Finally, because purchasers charge the manufacturer with responsibility for cars long after the actual sale is made, the relationship between merchant and manufacturer is close and vital. The retail merchant is the manufacturer's direct contact with the public, so that the manufacturer must depend upon the merchant to assist in maintaining his reputation and good will, built up over a period of years and as a result of extensive advertising.

The basis of the existing relationship between automobile manufacturers and merchants was brought out clearly by K. T. Keller, president of the Chrysler Corporation, speaking at a gathering of hundreds of dealers, when he said:

> The fundamentals of our relations with our dealers as we see them are these: First, a good product at a competitive price. Second, effective advertising and sales promotion to make the product known to the public. Third, a fair, business-like arrangement between dealer and factory on which a good merchant can make a success of selling and servicing that product.
>
> As this business is carried on today each of these three is essential to the others. All three are essential for your success and our own. And in all three we think the record is one on which both you and we can look with confidence and assurance that our mutual progress is continuing.

The automobile dealer. The automobile retail merchant, however, is not an "agent" of the manufacturer. He is strictly independent, for he not only buys his cars outright but also stores them until they are needed, bears the risks in storing them, and finances the transaction. Usually, the dealer is given exclusive right to his territory as a reward for

handling the product of one particular company. The arrangement between manufacturer and merchant is usually terminable at will upon specified notice by either party.

Financing the purchase of automobiles. In the early days of the industry, when motorcars were considered little more than an expensive luxury, the buyer expected to pay cash for his purchase. With the introduction of the low-priced car, however, this practice has been greatly modified. Mass production has made the automobile available to persons of moderate means, provided they are able to purchase it on time payments. Moreover, since the automobile soon became a business necessity as well as a pleasure vehicle, many individuals preferred to pay for their cars out of earnings, rather than to make the full initial outlay upon taking possession. The financing by dealers of motorcar sales on time payments was not possible, for the average dealer has only a limited amount of capital and needs much of this to make his purchases from the factory. Commercial banks did not care to enter the field because of the troublesome detail involved in small installment payments and the danger of having considerable numbers of repossessed cars on their hands. The result was that, beginning about 1915, automobile finance companies rapidly appeared to handle these time payments. Some of them were commercial credit companies already engaged in other fields, while a considerable number were organized for the express purpose of financing automobile sales. So widespread has this means of automobile purchase become that approximately 60 per cent of all cars in recent years have been bought on credit, which is handled by between 400 and 500 financing companies.

Export sales. The export market also plays an important part in normal times in the distribution of motorcars. The wars now being waged throughout the Eastern Hemisphere naturally have caused dislocations in the export market.

In times of peace, various methods of reaching the export market have been employed. Several important companies have maintained branch factories abroad to cultivate the market without paying high protective tariffs on imported automobiles. Other large American units in the industry have established branch assembly plants outside the United States to assemble into complete cars the parts shipped to them from this country and Canada, with distribution handled from the branch factory largely by dealers bearing the same relation to the factory that dealers do in America. Other exporters from the United States have maintained staffs of wholesalers in foreign countries who, in turn, distribute automotive products through resident dealers, while still other smaller manufacturers have been dealing directly with their distributors by mail and cable, thus eliminating considerable organization expense. The wars in Europe and in Asia have interfered with all these types of export activities and, in some instances, have caused them to cease entirely.

The importance of the export market for the American automobile industry is indicated by the following table showing the proportion of the total production exported during the period 1934 to 1939:

TABLE IV

EXPORTS AND FOREIGN SALES OF AMERICAN MOTOR VEHICLES

(000 omitted)

Year	*Total Production of Passenger Cars, Trucks, and Busses*	*Exports, Including Foreign Assemblies*	*Per Cent of Total Production Sold Abroad*
1934	2,870	427	14.9%
1935	4,120	508	12.3
1936	4,616	508	11.0
1937	5,016	683	13 6
1938	2,655	492	18.5
1939	3,733	472	12.6
1940	4,469	229	5.1

Reciprocal trade agreements negotiated with foreign countries by the United States Government since 1934 helped substantially during peacetime to reduce barriers to automobile export trade, but a large number of these agreements are now inoperative. Canada is the chief foreign market for automobiles made in the United States. Excepting Canada, the Union of South Africa, in recent years, has purchased more passenger cars made in the United States than any other country, while Argentina has been the leading export market for motor trucks.

Legislation Affecting the Industry

Federal legislation. An excise tax of 2 per cent on trucks and 3 per cent on passenger automobiles was imposed on automobile manufacturers by the Revenue Act of 1932, and in 1940 both these excise taxes were increased, the tax on trucks to 2½ per cent and the tax on passenger cars to 3½ per cent. The tax is paid on the sale price by the manufacturer or importer. The Federal Government also imposed a tax of 1 cent a gallon on gasoline in 1932, which was increased in 1940 to 1½ cents a gallon. Manufacturers in the United States enjoy tariff protection under Federal legislation, and there are also Federal laws governing the operation and ownership of motor vehicles

State legislation. Each of the 48 states and the District of Columbia have drawn up their own motor-vehicle codes, containing the laws and regulations in accordance with which it is necessary to operate in their particular commonwealth. As these codes differ widely in various parts of the country, widespread confusion and misunderstanding have often resulted.

The first legislation of the various states affecting the motor vehicle was related to safety and usually consisted of restrictions in the matter of speed. Originally, a low rate of speed was considered essential to safety of operation, but as motorcar design improved, the animadversion

against speed has tended to disappear, and in many instances, it has been found necessary to speed up the traffic to avoid congestion and overtaxing limited highway facilities.

With the increase in general use of the automobile, other restrictive legislation was also enacted in the interest of safety, for both the driver and the pedestrian. Almost all states have traffic codes prescribing how the car is to be driven under certain circumstances. The automobile owner also is required by law to equip his car with such accessories as headlights, taillight, brakes, horn, rear-view mirror, and muffler cutout. The size and weight of cars and trucks allowed on highways are also the subject of legislation in many instances.

Registration of motor vehicles. The first law requiring the registration of motor vehicles was passed in New York, in 1901. Other states followed in turn, so that, by 1914, every state in the Union required that all automobiles be registered, charging a fee for this privilege. At first, fees were always at a flat rate and registration continued automatically during the life of the car without renewal. Soon this was changed, however, to an annual fee, which had to be paid from year to year. At present, most states charge a sliding scale of registration fees, determined by the weight of the car or the horsepower of the engine. Income from this source amounted to $430,549.000 in 1939.

Gasoline tax. An even more important source of income from the automobile has resulted from the tax on gasoline for use in motorcars. From the States of Colorado, North Dakota, and Oregon, which taxed gasoline in 1919, the practice has spread rapidly, until now all states and the District of Columbia obtain substantial revenues in this manner. The tax varies in different states, ranging from 2 cents a gallon in Missouri and the District of Columbia to 7 cents a gallon in Florida, Louisiana, and Tennessee. In the calendar year 1939, $816,433,000 were collected by the states in gasoline taxes.[3] Most of the revenue yielded by these forms of taxation is expended for improving roads and highways throughout the country. Taxation of the automobile industry is thus in a large degree responsible for the rapid increase in the extent of good roads in this country, which, in turn, has been one of the most important causes of public interest in the motorcar and has contributed greatly to its popularity.

Motorbus regulation. Recent years have also brought increasing regulation of the motorbus, which has rapidly come to be one of the major means of transportation. In 1938, 49,200 common-carrier buses and 2,300 charter and sightseeing buses were in operation in this country. In 1940 there were 144,000 motor buses in use and 3,750,000 children were carried to school daily by buses. In most instances, bus lines are compelled to obtain certificates of convenience and necessity, in order to avoid unreasonable duplication of transportation facilities. Buses are also required to have public liability or indemnity insurance for the protection of passengers and the general public. Their rates and facilities

[3] Gasoline taxes, Federal, state, and municipal for 1940 amounted to $1,120,000.000.

are regulated by state authorities. It has been estimated that, altogether, some 2,000 rules regulating bus operation are on the statute books of the various states today. All these laws indicate the extent to which the automobile industry has been affected by legislation in the United States.

Future of the Industry

It is no less difficult today to forecast the future of the automobile industry than it was when the banker mentioned at the beginning of this chapter scoffed at the idea that 500,000 motorcars would be made annually in the United States. In the brief intervening period, the industry has contributed an epic chapter to the economic history of the nation. It has accomplished this by striving each year to give to the public greater values in products and services. That effort has kept progress on the march in the automobile industry. Automotive engineers are constantly testing new ideas and new methods for making better automobiles. From such engineering and from the hardheaded, sound management that enabled the industry to achieve efficient, large-scale production and distribution have flowed consumer benefits perhaps unparalleled in any other great industry, consumer benefits in the form of improved products and often at substantially reduced prices. These consumer benefits are reflected in the remarkable growth of the industry. Continuance of its traditional policy of giving motorists greater values each year would seem to assure the industry a future that may well be even brighter than its past.

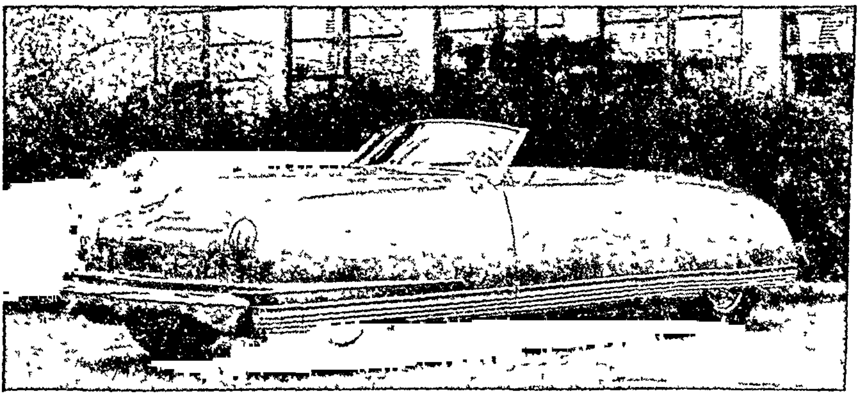


Fig 5 Forecasting the automobile of tomorrow—the Chrysler "Thunderbolt."

32

The Aeronautical Industry

Introduction

The aeronautical industry of today is in *reality* two industries. One is concerned with the manufacture of airplanes, engines, and such accessories as propellers, tires, and instruments; the other, with the transportation of mail, passengers, and merchandise on regular schedules over established routes. The problems and history of each are quite different. This difference is analogous to that between automobile manufacture and bus transportation.

Both branches of the aviation industry are similar in one respect, however: fundamentally, their existence has depended on Government support. The largest and most successful manufacturers of airplanes and engines are vendors of military planes and engines to the United States Army and Navy; and the largest and most successful air lines have been those that hold Government contracts for the transportation of mail. Of recent years, however, with wider acceptance of air transportation by the traveling public, passenger revenue is gaining equal importance with income derived from air-mail contracts.

There is nothing unique about this situation. All methods of transportation have required or still require Government assistance, either directly or indirectly. Expenditures for aeronautics so far have been considerably less than expenditures made to shipbuilders for warships; to railroads, by means of mail contracts and land grants; or to shipping companies, by means of mail contracts, out-and-out subsidies, and long-term loans at low interest rates. Aviation has received less support in the United States than in many foreign countries. All major nations realize that their aviation program is closely allied with that of national defense and for this reason, if for no other, must have government support. At the same time, a great manufacturing industry and new transportation system are being built up, which will have a marked effect on our future economic prosperity.

The Five Periods of Aviation History in the United States (Heavier-Than-Air Type)

An outline history of the aviation industry in the United States must recognize five definite periods. The first period was that of the pioneers, from 1895 to 1914. Then came that of the First World War, when military needs were dominant and when the industry reached an enormous volume of production. The third period came immediately after the war, when drastic deflation following the cancellation of war orders nearly wrecked the industry. This was followed by the period of commercial development, brought on by the public enthusiasm for the long-distance flights of 1927. The industry was in the later stages of this fourth phase, following an overestimate of the demand for airplanes among the general public—alleviated to some extent by the tremendous strides being made in air transportation, both of mail, express, and especially passengers—when, in the fall of 1939, with the outbreak of the present conflict in Europe, the American aircraft industry entered upon its fifth period of development—a period of stress-of-war expansion which bids fair to dwarf even the gigantic program undertaken and accomplished at the time of the First World War.

Period of the pioneers (1895 to 1914). In the United States, the names of the Wright brothers and Glen Curtiss stand out as the pioneer experimenters in the building of airplanes. With these names are linked those of Lincoln Beachey, Roy Knabenshue, and other outstanding pilots.

At first, airplanes were built only on order, and there were few purchasers. Each plane was a separate problem in itself, and improvements were made as they were conceived. It was not until 1909 that the United States Government ordered its first plane, and this was by no means the precursor to a flood of orders, for the Army and Navy showed, up until this country's entrance into the First World War, a marked reluctance to adopt airplanes in their services. One or two planes were purchased by private individuals, but they were little used; they were purchased more for display than for actual service. The aeronautical activities of this period consisted principally of racing and exhibition flights at fairs and other public occasions, interspersed with parachute jumps and sporadic experimental services, such as an air-mail flights between points on Long Island and bomb-dropping and machine-gun experiments on the part of the Army. Passengers were carried for hire on short flights, but few were willing to trust themselves to the airplane. In 1911, the first flight was made across the United States. It took nearly 7 weeks and was characterized by numerous forced landings.

Effects of the First World War on the aeronautical industry. The outbreak of the First World War was marked by a period of hesitancy as to what the function of the airplane was to be. The issue was not long in doubt, however, for the early supremacy of the Central Powers in the air was largely credited for the success of their campaigns during the first year of the war. Following this came a hasty attempt to increase

the air force of the Allied Powers, and American and European airplane builders were kept busy night and day filling orders. With the entrance of the United States into the war, American builders, with a production capacity of 5,000 planes annually, were told to prepare to turn out 25,000 a year. In spite of this staggering increase and the attendant difficulties, by the end of the war the productive capacity had been obtained, and 16,000 airplanes with engines, as well as 25,000 separate engines, had been produced. Then came the Armistice, the cancellation of Government orders, and as complete a collapse as any industry has had to face.

Aeronautical industry after the First World War. For the next few years, the industry made little progress. Many companies liquidated or were forced into bankruptcy after the curtailment of Government orders, and the Government's policy of selling its surplus equipment at almost any price and its failure to provide funds for experimental construction on any adequate scale did nothing to alleviate the situation. Hundreds of war flyers purchased surplus equipment and flew through the country on barn-storming tours, giving exhibitions of flying and parachute jumping, and taking passengers on short flights. The system was a disorganized one, and there were no regulations assuring the passenger of the safety of the plane he flew in. Accidents were frequent, and progress in the science of aeronautics was slow. However, one event of importance to commercial aviation took place during this period. In 1918, the first regular air-mail service in the world was instituted by the Post Office Department between New York and Washington. This service was the precursor of the present far-flung system of regular air lines.

Period of commercial development. Progress may have been slow, but it was definite. The Post Office air-mail service was extended across the continent, and, from less than 5,000,000 letters carried in 1918, a peak of more than 65,000,000 letters was carried in 1924. Since the late 1920's, the growth of the air-mail service has been such that the Post Office Department abandoned the counting of pieces of air mail as a statistically impossible measure of the service performed and, instead, issued figures on miles of operation carried out. In this regard, it is interesting to note that, for the entire year 1918, when regularly scheduled air mail had its birth in this country, a total of 16,000 miles of air-mail operations were flown, while for 1939, this figure had jumped to 52,193,772 miles. This is surely a phenomenal growth.

In 1925, the first real impetus was given to commercial aviation when the first contracts were awarded for mail transportation to private companies, which then superseded the Government service. At the same time, engineering research was resulting in improved reliability of engines and serviceability of planes. The Air Commerce Act of 1926 placed aviation on a rational and legal basis. These developments set the stage for the successful long-distance flights of 1927 and the consequent public enthusiasm for aeronautics.

The flights of Lindbergh, Brock and Schlee, Goebel, Chamberlin, Mait-

land and Hegenberger, and of Byrd, Acosta, and Balchen, in 1927, brought the first widespread recognition to aviation. Eager investors, encouraged by the bankers, bought stocks, and money poured in. Patrons crowded the air fields to take short flights. The demand for airplanes for such services rose beyond the productive capacity of the industry, and continued so until the summer of 1929. Many new companies were organized to meet the apparently inexhaustible demand.

Unfortunately, the demand was exhaustible, and it declined sharply in 1929, throwing a number of companies into bankruptcy and demoralizing the market by cut-price competition. The industry was slow to recover from the effects of this shock, which, combined with the general decline in business conditions, made for drastic deflation.

Aviation is transportation, and the first substantial commercial development was the carrying of passengers, mail, and express over regular scheduled runs. The development of the market for the privately owned plane will follow, but more slowly, and its size and popularity will depend upon the ingenuity and ability of the engineers, who must produce a foolproof airplane that is easy to fly and economical to purchase and operate.

Early History of Heavier-Than-Air Craft

The Wright brothers' experiments. When, on December 17, 1903, Wilbur and Orville Wright put an airplane into free flight for the first time in human history,[1] no public reception committees and showers of ticker tape greeted the accomplishment. The flight either was ignored or was received with ridicule and incredulity. Within 15 years, governments were to spend millions upon millions of dollars to gain control of the air in the First World War.

The work of the Wright brothers was preceded by studies of gliding by Lilienthal and Chanute, which resulted in many successful flights. Langley and Maxim contributed by their studies of powered flight; actual flights were attempted, but were not successful. The Wright brothers carried on from this point, but they found so much conflicting material in the records of previous researches that they decided to begin from the start. In October, 1900, active experiments were started at Kitty Hawk, North Carolina, with man-carrying kites as laboratory material. From these, the work progressed to gliders, finally ending in success with the first powered flight of 12 seconds, in 1903.

An outline as brief as this can give but an inadequate idea of the difficulties that faced pioneers in aeronautics. It is interesting to recall, in this connection, that the design of the propellers for the first airplane occupied several months of study and argument between the Wright

[1] Evidence exists that Clement Ader flew a distance of 300 meters in a machine of his own invention in France, in 1896, but it is somewhat less conclusive than the evidence of the Wright brothers' flight. In any event, Ader failed to carry on from that point, while the Wright brothers continued to study and experiment.

brothers, after which each was converted to the other's point of view, with a net gain of nothing!

Evolution of the principles of aerodynamics. From the time the Wright brothers made the first flight, the history of the airplane is one of refinement of detail and increase in reliability. The aerodynamic principles evolved by the Wrights are essentially those of today, although more is known about them. Men who made important contributions to this increase in knowledge are Santos-Dumont, who, in 1906, made the first flight in Europe in an airplane of his own design; Bleriot, who built the first monoplane in 1906, and who is chiefly remembered for the first flight across the English Channel in 1909; and Curtiss, who added important refinements in airplane and engine design and construction, developed the seaplane and the flying boat, and made many memorable flights.

First flight of the autogiro. In January, 1923, at Madrid, Spain, Juan de la Cierva made the first successful flight in an autogiro, which marked the first practical departure from the design of heavier-than-air craft developed by the Wright brothers. Because of its comparative safety, high angle of take-off, and low forward speed for landing, and its ability to descend vertically at a speed slower than a parachute should the engine fail, the autogiro contains great promise for the wide development of private flying. Its present disadvantages are low speed, limited carrying capacity in relation to horsepower expended, and certain difficulties in handling. However, experimentation has continued and most recent developments have resulted in the so-called "jump" autogiro, referring to its ability to take off almost vertically with only negligible ground run.

The first helicopter. The helicopter has had a good deal of attention from inventors over the period covered by the development of the airplane, but little progress has been made in comparison with vast strides made in airplane design and performance improvement. Just before the outbreak of the present war, there had been produced in Germany, by the Focke-Wulf Company, what seems to have been the first commercially practicable helicopter. It is understood that a great deal of test flying was carried out under varying conditions, and such details of the machine and the flight-test results as had been released prior to the clamping down of war censorship seemed to bear out the claims of the designer regarding its practicality. It was no doubt a craft of this type that was reported to have played so important a part in the reduction of the Liége Forts when the Nazis invaded Belgium in the spring of 1940. Several American aircraft constructors are presently engaged in the development and building of a number of helicopters, and it is the opinion of a great many in the aeronautical industry that the helicopter will play an important part in the future of aeronautics, both military and commercial.

Early History of Lighter-Than-Air Craft

The history of lighter-than-air craft begins on June 5, 1783, when Stephen and Joseph Montgolfier's hot-air balloon made a successful flight in France, but without passengers. Later that year, the first passengers were carried. In 1852, in Paris, Henri Giffard equipped a spindle-shaped balloon with a 3 horsepower steam engine, and made a successful flight at a speed of 6 miles an hour. In 1898, Santos-Dumont began to develop the first practical airship, which was followed by Count Ferdinand von Zeppelin's invention, a rigid dirigible with separate gas bags, completed July 2, 1900. From Zeppelin's design have been developed such modern rigid airships as the *Graf Zeppelin, Macon, Los Angeles* and *von Hindenburg* Unfortunately, the history of lighter-than-air craft, particularly of the Zeppelin type, has been marked by a series of disasters that have seriously hampered progress in this field. The discovery in the United States of helium, a noninflammable buoyancy gas, for use in these craft—in lieu of the highly dangerous hydrogen gas—has solved one of the many problems involved. But there are still a great many more to be tackled and solved before the Zeppelin or some similar type of lighter-than-air craft takes its place as the giant transoceanic air freight of the future which a school of thought in aviation circles holds will be its niche.

Economic Significance of the Aeronautical Industry to Our Present Industrial Development

Importance of the airplane to business. The airplane is the fastest known commercially practicable means of transportation. Speed has attained a definite premium in present-day business, and it is here that the airplane performs its greatest economic function. Businessmen using airplanes have found that it is now possible to visit two or three cities in one day, a trip which, by railroad, might require as many days as there are cities to be visited. Sales executives have made tours of their principal outlets or branch offices in 1 week by air, where the same trip by automobile or railroad would have required 3. The air-line time between Cleveland and Detroit is 30 minutes; the time by rail is several hours. Similarly, a businessman may leave Chicago for New York by air in the early afternoon, after having the morning free for business, and arrive that night in ample time for dinner. New York is 16 hours from San Francisco by air, as against several days by rail. Pittsburgh is an overnight trip by rail and a trip of 135 minutes by air. Similar comparisons can be made between important cities, not only throughout the United States but throughout the world. Air transportation makes possible personal supervision over a wider area, and it will play its part in a tendency toward larger business units.

The same situation holds true with air-mail and express services. Air mail has saved large sums for banks in interest charges on financial

transfers. Rush shipments of merchandise and spare parts for expensive machinery have saved large sums for industry.

Effect of the airplane on international relations. In another way, less direct but larger in its ultimate implications, air transportation will have an effect on our economic structure. It is bringing hitherto distant and more or less inaccessible nations and regions into closer touch with the rest of the world. The result should be better international relations and a continued growth of the realization that the nations of the world are interdependent. New markets will be opened up, new uses for the products of backward countries will be found, and a general increase of human welfare will result—with this qualification: as an instrument of war and conquest, the airplane has greater potentialities than any yet developed. If used in the wrong way, the possibilities are appalling

The growth of air transportation has not been confined to the continental limits of the United States but has been constantly reaching out, starting ever-expanding feeder air lines from important United States cities to sister republics of South America, so that today, not only is the United States criss-crossed by a network of air lines, but every important city up and down the east and west coasts of South America, as well as a great number of those located in the interior, are linked together by air-transport operations.

American pioneering spirit responsible for the realization of man's centuries-old dream of flying has also taken the lead in the application of the airplane to transportation. Having covered the Western Hemisphere with a network of air lanes, tentative feelers were extended across the oceans; and after a decade of development, they have been conquered—both the Atlantic and the Pacific—and United States air-transportation systems cross the water and connect with the air lines of Europe and the Orient. The outbreak of the present conflict in Europe found trans-Atlantic and trans-Pacific air-service schedules increasing monthly; and while hostilities have caused some retarding of the normal growth of this development, stress of war conditions incident to the lack of hazards of surface shipping are serving in some instances to accelerate this growth.

The airplane as an agent of diffusion of population. A third effect that air transportation may have on our economic structure will be in wider diffusion of population. Just as the automobile increased the average man's radius of action and enabled him to widen his circle of acquaintanceship and to live a greater distance from his work, so the private use of the airplane will push back his horizon still more.

Every new invention that has improved and speeded up our transportation and communication systems has contributed to our present high state of civilization. The airplane, because of its newness, speed, and freedom of action, may outrank the telephone, telegraph, radio, railroad, steamship, and automobile in shaping future progress.

Important Companies within the Industry

The history of the aircraft industry in the United States has been one of ups and downs of manufacturing activity, affected both by the ex-

pansion needs of wartime and the barometer of general business conditions during periods of peace. In 1931, there were approximately 175 companies in the United States engaged in the manufacture of aircraft. Less than 50 were of any great importance, since the majority of the companies consisted of experimental builders operating on a very small scale; approximately 30 companies were manufacturing airplane engines, but here again the majority were small experimental builders; 24 companies carried on the major portion of air-transport operations in the United States.

During that time and the present, many of these companies fell by the wayside, victims of the general slowing up of economic conditions throughout the world, the survivors being those with the greatest experience and those who realized that the backbone of the industry was continuous engineering and research, and who, as a result, maintained strong engineering staffs that, although supported by "rationed" engineering budgets, were never entirely eliminated.

According to the statistics for 1940, among the aviation companies of major importance were:

Curtiss-Wright Corporation, a holding company including the following subsidiary and divisions:
- *Wright Aeronautical Corporation* (a subsidiary): manufacturing a complete line of air-cooled engines (225 H.P. to "over 2,000 H.P.") for military and commercial uses.
- *Curtiss-Wright Airplane Division:* Manufacturing airplanes for military and commercial uses.
- *Curtiss-Wright Propeller Division:* Manufacturing electric "full-feathering" propellers for military and commercial uses.
- *Curtiss-Wright Export Sales Division:* Handling the export business of the units of Curtiss-Wright Corporation.
- *Curtiss-Wright Airports Division:* Owning and operating a number of major airports.

United Aircraft Corporation, a holding company including the following subsidiaries and divisions:
- *Pratt & Whitney Aircraft Division*: engaged in the manufacture of air-cooled engines for military and commercial uses.
- *Hamilton Standard Propeller Division*
- *Vought-Sikorsky Aircraft Division*
- *Export Division*
- *United Airport Division*
- *United Aircraft Service Corp.* (Subsidiary)
- *Canadian Pratt & Whitney Aircraft Co.* (Subsidiary)

Consolidated Aircraft Corporation, engaged in the manufacture of military and commercial airplanes.

Douglas Aircraft Company, engaged in manufacturing military and commercial airplanes

The Glenn L. Martin Company, manufacturers of military and commercial airplanes.

Lockheed Aircraft Corporation, manufacturing military and commercial airplanes.

North American Aviation, Inc., manufacturing military and commercial airplanes.

Boeing Aircraft Company, manufacturing military and commercial airplanes.

Other companies engaged in manufacturing aircraft and engines are:
- Aeronautical Corporation of America
- Allison Engineering Co.
- Beech Aircraft Corporation
- Bell Aircraft Corporation
- Brewster Aeronautical Corporation
- Cessna Aircraft Company

Continental Motors Corporation
Fairchild Engine & Airplane Corporation
Grumman Aircraft Engineering Corporation
Jacobs Aircraft Engine Company
Northrop Aircraft, Inc.
Piper Aircraft Corporation
Republic Aviation Corporation
Ryan Aeronautical Corporation
Taylorcraft Aviation Corporation
Vultee Aircraft Inc.
Warner Aircraft Corporation

Major companies of the United States engaged in operating domestic and foreign air-transport lines in 1941, included:

Pan American Airways, operating an international air line linking the United States with Latin America, Alaska, Europe, and the Orient.
Transcontinental & Western Air, Inc., operating one of America's three coast-to-coast air lines.
Eastern Air Lines, operating routes serving the Eastern seaboard and Midwestern area
American Airlines, operating one of the nation's three transcontinental lines.
United Air Lines, operating one of the three major coast-to-coast routes
Braniff Airways, operating a North-South route linking the industrial Great Lakes, the trading Kansas City areas, and the fast growing Southwest.
Pennsylvania-Central Airlines, linking the Great Lakes area with the steel and industrial regions.
Northwest Airlines, operating between Chicago and the Pacific coast, serving the major northwest cities.
Chicago & Southern Air Lines, linking Chicago with the major cities of Mississippi Valley.
Western Air Lines, operating a north-south line in the territory west of the Rocky Mountains.

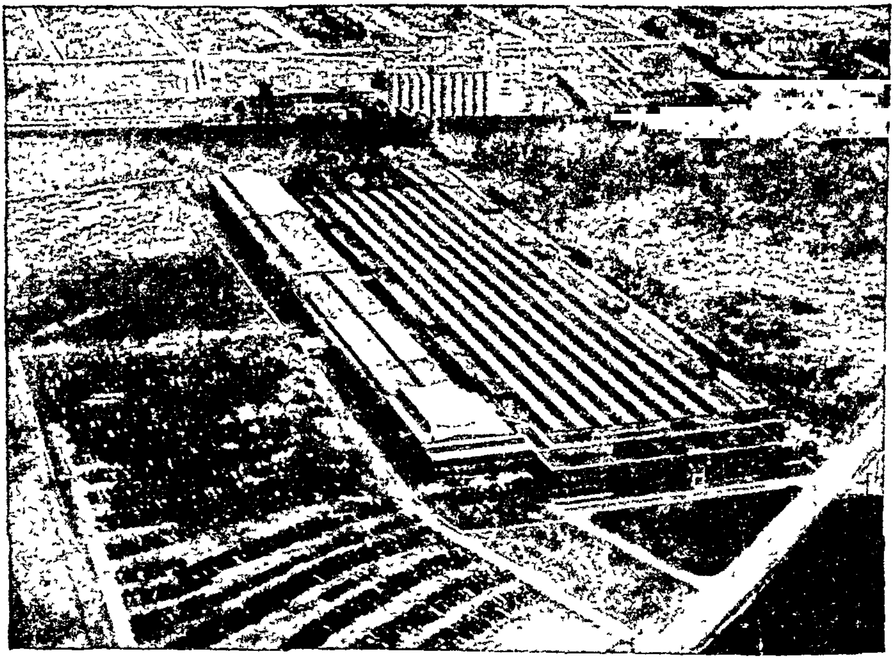
Geographical Location of the Aeronautical Industry

Dayton, Ohio, and Hammondsport, New York, were important names in the early days of aviation. Although their importance as aeronautical centers has faded, they represent the general alignment of manufacturers today, fairly equally divided between the East and the Middle West During the First World War, the East dominated airplane production, although a large proportion of the wartime airplane engines were produced in Detroit. Since that time, activities have been more scattered, although in view of the apparent desirability of an even climate that will eliminate costly delays incident to delays in flight testing of products, there has been a trend to locate a great number of plants on the Pacific Coast, in southern California.

Many factors influence the location of an airplane or an engine plant. Among the most important of these are local pride, labor supply, and accessibility to markets. None of these factors has been sufficiently important to cause a general localization of the industry, with the result that airplane factories are found throughout the United States. Engine factories are a little more localized More recently another important factor has come to the fore regarding the location of aircraft manufacturing plants, namely, strategic location from the military standpoint

with reference to establishing plants in the center of the country rather than on the Atlantic or Pacific coasts. This principle is being followed voluntarily by the industry and is also being specified by the military authorities in connection with certain expanded plant facilities being sponsored by the Government for wartime production.

Important factories for the manufacture of military and naval planes are located in East Hartford, Connecticut; Buffalo, New York; Bristol and Philadelphia, Pennsylvania; Baltimore, Maryland; Burbank, Inglewood, and Santa Monica, California; and Seattle, Washington.



Courtesy, Curtiss-Wright Corporation

Fig. 1. An aerial view of the Buffalo, New York, plant of the Curtiss-Wright Corporation.

Commercial planes are manufactured in important numbers in Santa Monica and Burbank, California; Seattle, Washington; Baltimore, Maryland; St. Louis, Missouri; Lock Haven, Pennsylvania; and Alliance, Ohio.

The larger engine manufacturers have factories in Paterson, New Jersey; East Hartford, Connecticut; Cincinnati, Ohio; Indianapolis, Indiana; Muskegon, Michigan; Pottstown and Williamsport, Pennsylvania; and Farmingdale, Long Island.

Methods of Manufacturing

There is little similarity between the manufacture of airplanes and that of airplane engines. Essentially, engine production is a machine

process. Although highly skilled workmen must be employed, these workmen perform their duties largely through the use of machines. The airplane, on the other hand, is principally a product of hand labor. The chart in Figure 2 outlines the organization of the Wright Aeronautical Corporation, a prominent manufacturer of engines. In most respects it is similar to those of other types of manufacturing companies. The prominence given to the inspection and quality departments and their relative independence emphasize their importance in aeronautical manufacture.

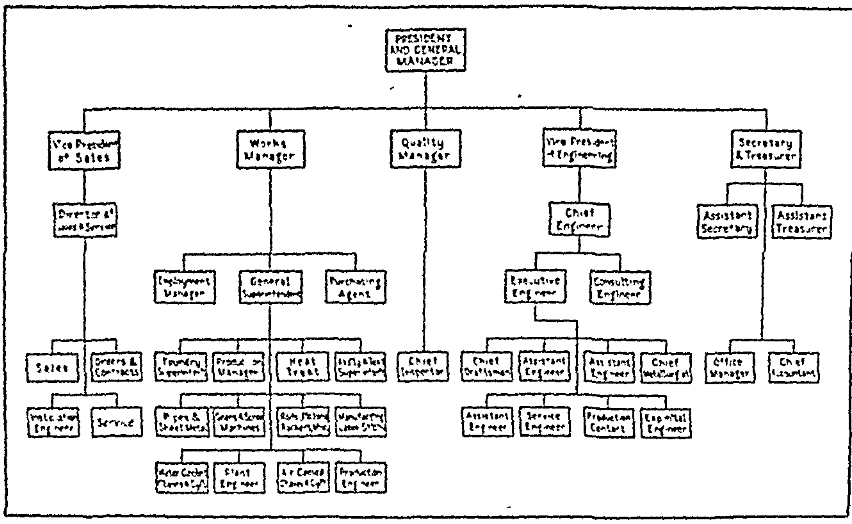


Fig. 2. Organization chart of the Wright Aeronautical Corporation

The engine. *Casting and machining.* The first stage in making a Wright Cyclone radial, air-cooled engine takes place in the foundry, where special furnaces melt aluminum alloys preparatory to casting them in molds. The rough castings then are machined. At the same time, drop forgings purchased from outside sources are being machined, after having been given rigid tests to determine hardness and other structural qualities. The exposed parts of the engine are given rustproofing treatments, and the castings are heated and immersed in oil to harden the surfaces.

Next, the aluminum cylinder head is joined to the steel cylinder sleeve. The head is heated and screwed to the sleeve, which is cold; and when the head contracts in cooling, the two are locked together. The unit then is sent to the painting room, where the finish is sprayed on and baked.

Meanwhile, the other parts of the engine are being buffed by machine and polished to a mirrorlike surface. All parts are again inspected, and even a surface scratch will cause immediate rejection. Spot-welding

of manifolds and of other parts requiring similar treatment is done in another department by electric machines.

Assembly operations. The parts then are moved to the assembly floor. Here they are placed until needed on stockroom shelves, on the right of the assembly room. From these shelves, various parts assembly lines run out at right angles. At the end of the parts assembly lines is the primary assembly line.

Courtesy, Curtiss Wright Corporation

Fig 3 Wright Cyclone engines of 1,600-1,700 H.P are shown being assembled in the final assembly department of a plant of the Wright Aeronautical Corporation in Paterson, New Jersey

The assembly starts at the stockroom shelves Each parts-assembly bench draws from the stockroom the finished parts that it must assemble The crankcase is tapped, and smaller parts are attached to it On other lines the crankshaft moves down, the cylinders are fitted, and the master rod and articulating rods are connected to the pistons.

Engine testing. At the beginning of the primary assembly line, the crankcase is placed on a four-wheeled table and, as the table moves down the line, the engine is assembled as it picks up the parts from their assembly lines. After completion of the assembly, the engine is placed in the test house, where a four-bladed wooden propeller is attached, and it is run at high speed for 5 hours. In a small room at one side, an

observer keeps constant watch over the instruments recording the performance of the engine.

When this test is successfully finished, the engine is completely disassembled, and each part is thoroughly cleaned and rigidly inspected. Once more, the engine is assembled, this time on the secondary assembly line, and is given a further 2 hours of testing. It is then ready for delivery.

The plane. The manufacturing methods employed in the construction of an all-metal Curtiss-Wright military pursuit airplane may be taken as typical, since, although this is a fairly small single-place ship, the same principles and practices are followed for even the largest military bombers or commercial transports.

The first point to note is that there has been a radical change in airplane construction since the Wright brothers first taught the world to fly.

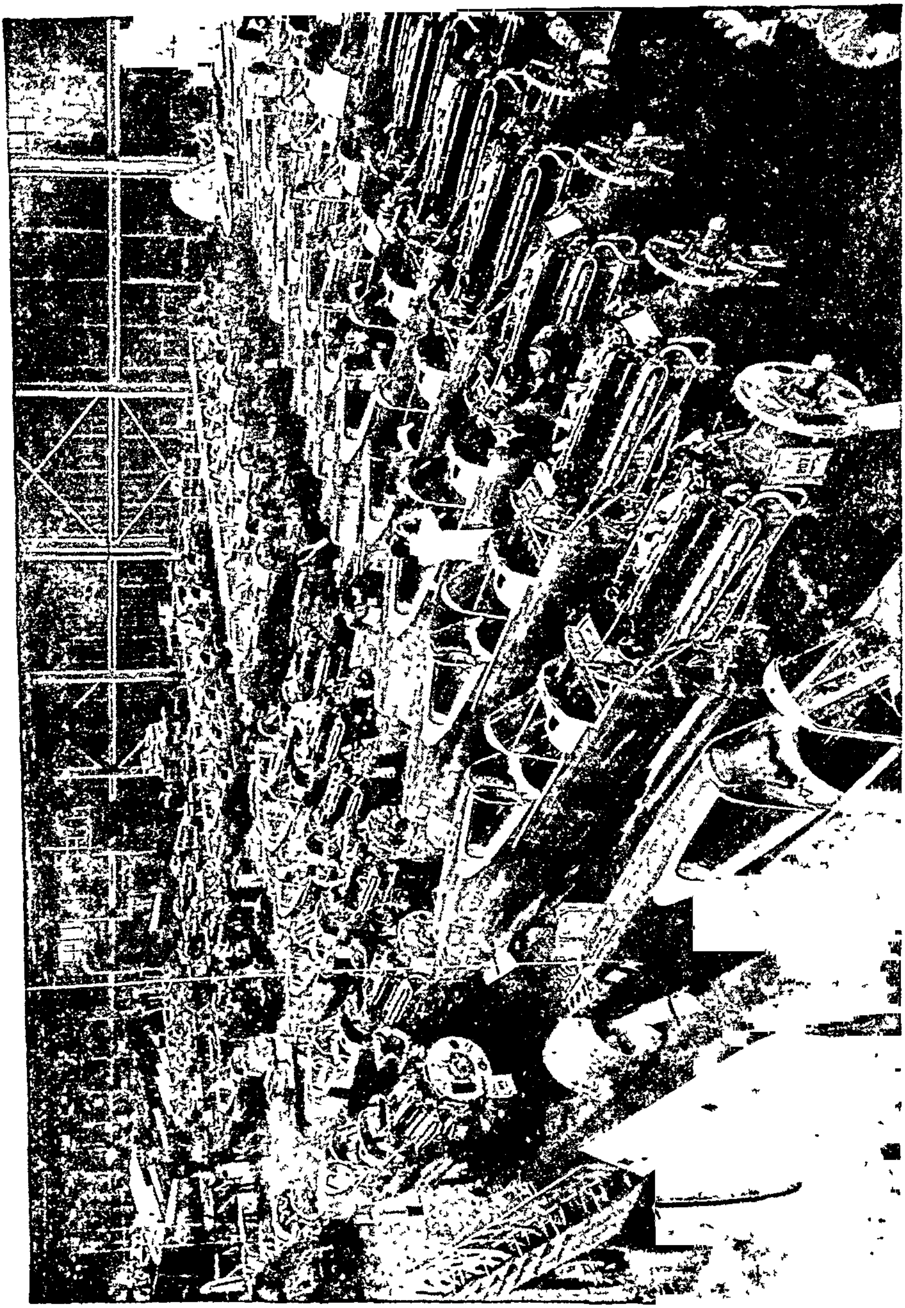
Up until and through the First World War, so-called "stick-wire-and-cloth construction" maintained. The frame or fuselage skeleton and the skeleton framework of the wings were constructed of wood, with a limited number of steel fittings in certain highly stressed parts. These frames were then covered with cloth, cut and sewed to proper size, and then treated with several coats of dope, which, as it dried, caused a shrinking of the cloth, making it taut, tight, and snug.

As will be realized, this construction resulted in a rather fragile product, which had to be operated and maintained with the greatest care. After much development work, metal slowly began to take the place of wood in aircraft construction; and in the late 1920's, current practice was to manufacture the fuselage skeleton of steel tubing for later covering with cloth, while the wings were still of the stick-wire-and-cloth construction.

As the years progressed, experimentation went forward, and with the parallel development of aluminum and similar lightweight metals, the early efforts of Ford in this country and Junkers in Germany looking to the development of an all-metal plane attained commercial practicability; and first steps were made in the evolution of a construction known as the "stressed-skin monocoque type," which is practically standard throughout the industry today except in the very lightweight, low-priced, private-owner type of craft.

Along with the evolution in manufacture, there has also been a trend in design away from the two-wing, biplane type of craft to the one-wing, monoplane type. In some instances, this single wing is mounted above the fuselage, when it is called a high-wing monoplane, while in others—and by far the vast majority—it is mounted flush with the bottom of the fuselage to produce the low-wing type of monoplane.

After the contour, or airfoil section, of the wing has been decided upon, ribs stamped out of sheet aluminum or one of its alloys on a hydraulic press are assembled on metal spars of similar material, which run the length of the wing and form its backbone. After this skeleton assembly has been completed, it is then covered with thin sheets of aluminum riveted into place. Constant care and inspection that will pass only



Courtesy, Curtiss-Wright Corporation

the highest type of workmanship are maintained throughout fabrication.

Fuselage construction. The fuselage is also constructed of all metal, and is in the form of an approximately oval shell. A series of oval bulkheads, varying in size from the front to the rear of the airplane, are stamped out of aluminum-alloy sheet and set up in a metal jig The outer covering or skin of sheet-aluminum alloy is applied and riveted in place, thereby producing a hollow monocoque shell in which the sheet metal covering not only forms the cover for the fuselage structure but also assists in keeping the fuselage structure intact and carrying some of the load; hence the name "stressed-skin construction."

When the fuselage shell is removed from the jig, the power plant or engine is installed; the wing, tail, and landing gear following in close order as the air frame (as it is called at this stage) proceeds down the final assembly line.

Plane completed and tested. The next step consists of the installation of instruments, connecting control wires with the controls, the installation of seats and upholstering, and a thousand other details. Finally, the engine is installed, the necessary connections are made, and the plane is ready for its test flight. An experienced pilot makes the first flight, and the plane is put through all types of maneuvers in order to test its strength and control system, and to break it in. After successfully passing this test, the plane is given a thorough inspection, and it is then ready for delivery.

Possibilities of mass production. In the airplane industry as we know it today, the possibilities of mass production are only just beginning to be scratched. As the manufacture of airplane engines is done largely by machines, one machine performing a large number of operations simultaneously might replace a number of single-operation machines were the demand large enough to warrant the investment.

Heretofore, the principal reasons why such applications would have been unwise have been the relatively limited demand and the small number of units previously produced to which the overhead of machine equipment could be allocated. Other difficulties have been the extreme care necessary in fabricating the engine and the necessity of frequent and rigid inspection, although it is possible that these factors alone would not prevent further use of automatic machinery.

This entire situation is being put to the test at the present writing incident to the vast expansion being carried out in the aircraft and aircraft engine industry, having as its goal the production of the maximum number of units for delivery to our air forces and, as well, assisting Great Britain in her present struggle against tremendous odds and under the most trying difficulties from an orderly production standpoint.

Comparison of automobile and aeronautical engines. Perhaps the most graphic method of realizing the degree of difference in method that must exist between the manufacturer of an airplane engine and that of an automobile engine is to recall that the typical automobile engine, in the medium price range, is built to deliver 90 H. P. at 3,100 RPM; that its weight is approximately 7 pounds per horsepower delivered; that it

runs, on the average, at only 40 per cent of full throttle; and that its useful life is rarely over 75,000 miles. On the other hand, the Wright Cyclone nine-cylinder radial engine delivers 1,200 H.P. at 2,500 RPM, weighs only 1.09 pounds per horsepower, averages 85 per cent of full throttle operation in normal service, and has a useful life of more than 10,000 hours—or between 1,500,000 and 2,000,000 miles. Such wide differences in performance requirements inevitably have an important influence on manufacturing methods.

Types of Aircraft

There are two types of aircraft: those lighter than air, whose ability to rise is due to the fact that their total weight is less than that of an equal volume of the surrounding air; and those heavier than air, whose ability to rise is derived from the forces set up by air currents generated by motion relative to the surrounding air. In ordinary terminology, these two classes are known as "balloons" or "airships," and "airplanes," "autogiros," or "helicopters."

Balloons. *Nonrigid.* Three types of balloons are of importance. The first, the nonrigid, owes its shape entirely to the pressure of the gases within its envelope. It is exemplified by the balloons used in the Gordon Bennett Cup Races; by military observation balloons; and by the so-called "blimp," the only one of this type that is powered and therefore independent of air currents. Balloons can be either free or captive, depending on whether or not they are fixed to a ground station by cables. In actual practice, the only important type of captive balloon is that used for observation; other types are almost invariably free.

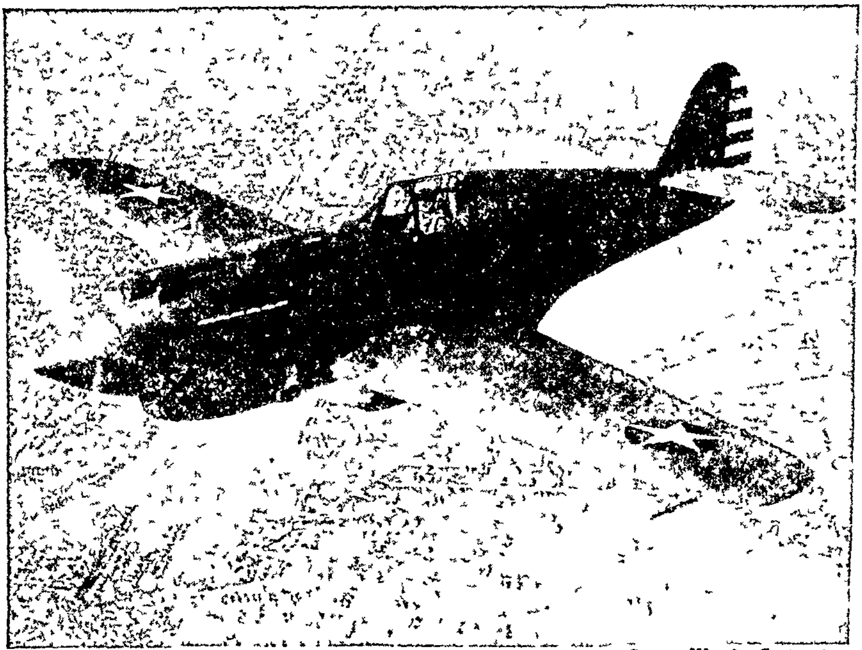
Semirigid. The semirigid balloon, of which the *Norge* of Arctic fame is an example, is of the second type. A substantial keel of metal or other rigid substance supports the bottom of the cigar-shaped envelope, holding its longitudinal shape. Vertical shape is derived from the pressure of the interior gases alone.

Rigid—the dirigible. From a commercial point of view, the third type, the dirigible, is the most important. It is directly derived from the designs of Zeppelin, and is exemplified by such ships as the *Graf Zeppelin, Los Angeles, Akron,* and *von Hindenburg.* Its cigar-shaped outer envelope is supported entirely by an inner structure of metal. Unlike the gases in other types of balloons, the lifting gases are divided among a number of inner envelopes to give greater protection in time of war and greater safety in time of peace. The dirigible can be built to a much greater size than other balloons, and its commercial possibilities are infinitely greater because of the greater pay load possible. Within this classification falls the metal-clad airship, which is necessarily rigid but carries gas directly in the envelope instead of in smaller bags within the hull.

Heavier-than-air craft. Heavier-than-air craft may be divided into airplanes, autogiros, and helicopters. The first is the conventional type, and is represented by triplanes, biplanes, sesquiplanes, and monoplanes,

with the monoplane clearly predominant. The triplane is unimportant. Biplanes and monoplanes are the most popular classes, and their terminology is self-explanatory. The sesquiplane, which has attained some degree of importance, consists essentially of a large upper wing and a lower one of less than half the size.

The autogiro. In the autogiro, the engine and the propeller provide forward motion; and revolving vanes, shaped like the conventional airfoil, unconnected with the engine, and deriving their motion from the air currents set up by the forward motion of the vehicle, provide the



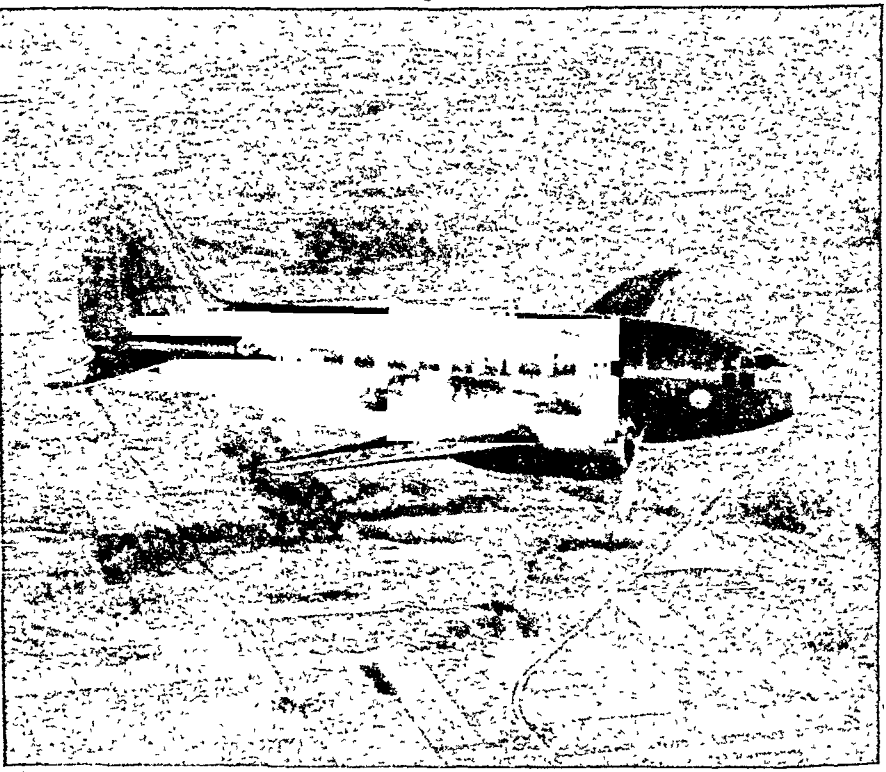
Courtesy, Curtiss Wright Corporation

Fig 5 Exemplifying military aviation is this Curtiss P-40 pursuit plane of the U S Army Air Corps Planes of this type are now being delivered to the Air Corps in large numbers

necessary lift. An autogiro was first flown in 1923, but not until 1931 was this type of aircraft marketed commercially Experimentation and development have been continued in this field, but the progress achieved has not been of the order of that attained in other classes of aircraft, principally because it has not been possible to obtain the speed range inherent in other types of aircraft—and speed, it must be remembered, is the *raison d'être* of the airplane. The latest type of autogiro, the so-called "jump" model, has an arrangement whereby the rotor vanes may be meshed into and driven by the power plant during take-off, so that ascent is practically vertical, with almost no ground run whatsoever. Only a few of this type have been produced to date, and further

time and testing will have to elapse before a verdict can be rendered.

The helicopter. The helicopter has been a favorite subject of inventors for many years, but progress has been slow. One of the difficulties in this design is that the true helicopter must fill six requirements: It must lift itself vertically off the ground, hover indefinitely over a given spot, descend vertically under its own power, achieve safe descent in event of engine failure, move horizontally at a satisfactory speed, and be controllable and stable under all flight conditions. The first commercially



Courtesy, Curtiss-Wright Corporation

Fig. 6. A modern transport plane: 36-passenger Curtiss-Wright powered by two 1,700 H.P. Wright Cyclone engines and designed to fly at altitudes of 20,000 to 30,000 feet.

practicable models are just being produced, and since the helicopter has the same limitations as regards speed that are present in the autogiro, it has only a limited military value, and therefore this field of endeavor in aircraft development is likely to remain dormant until after the end of the Second World War. It is interesting to note that it is the considered opinion of a great many in aviation that some form of autogiro or helicopter is the eventual answer to the so-called "private-owner market," or airplane for the man in the street.

Types of heavier-than-air craft. Heavier-than-air craft may be divided further into cabin and open types (with true open types fast disappearing, since even those airplanes that would normally be of the open type are all being equipped with portable cabins or pilot enclosures of transparent plastic materials), and into landplanes, seaplanes, flying boats, and amphibians. The landplane, operating from an ordinary land airport, is the conventional type. The seaplane is essentially a landplane, with pontoons substituted for landing wheels. The flying boat is designed solely for operation from the water, and usually the fuselage itself is the flotation unit, built in the general shape of a fast boat, and supporting the wings and tail directly. The amphibian operates both from land and water. Its hull is boat-shaped; but a landing gear is also attached, which, by a retractible device, may be drawn up out of the way when water operations are carried on.

Relative merits of classes of aircrafts. The relative merits of heavier-than-air and lighter-than-air craft have been widely discussed, and there are avid proponents on each side. From past experience, however, the heavier-than-air craft appears to be by far the faster and *the more practical for short and medium distances. It is handicapped* by its dependence on engine power for flight, and engine failure is sometimes a serious matter. The lighter-than-air craft (such as the dirigible) has an infinitely greater practical cruising range than the airplane, provides more comfort for passengers, and has an added safety factor in its independence of engines for staying in the air. On the other hand, it is slow, requires a large ground organization for landing—except where special equipment is provided—and costs considerably more to build than an airplane designed to carry an equal pay load.

Statistics of Aeronautical Production

Production of lighter-than-air craft, for the past decade, has been confined to a few units annually for military use. The last large dirigible construction undertaken in the United States was the *Akron*, completed and delivered to the United States Navy in 1931.

Detailed information and data pertaining to current actual and potential aircraft production in the United States have been placed on the restricted list by the military authorities, so that the usual table provided at this juncture must be omitted from the present edition of this work. In lieu of detailed figures, the following charts showing actual and estimated over-all productive capacity of the United States aircraft industry will be found enlightening as to the phenomenal growth of the industry. Particular attention is called to the fact that these charts pertain solely to military aircraft production and do not include commercial aircraft of private owner or air-transport classes, the development and production of which are in a great measure being subordinated to the producing of military craft just now.

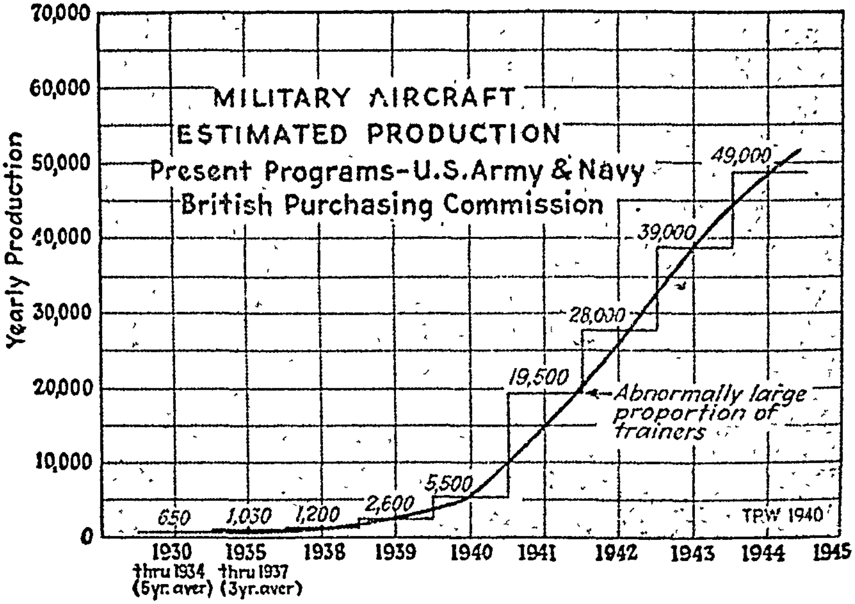


Fig. 7. Yearly production of military airplanes in the United States and estimated future production.

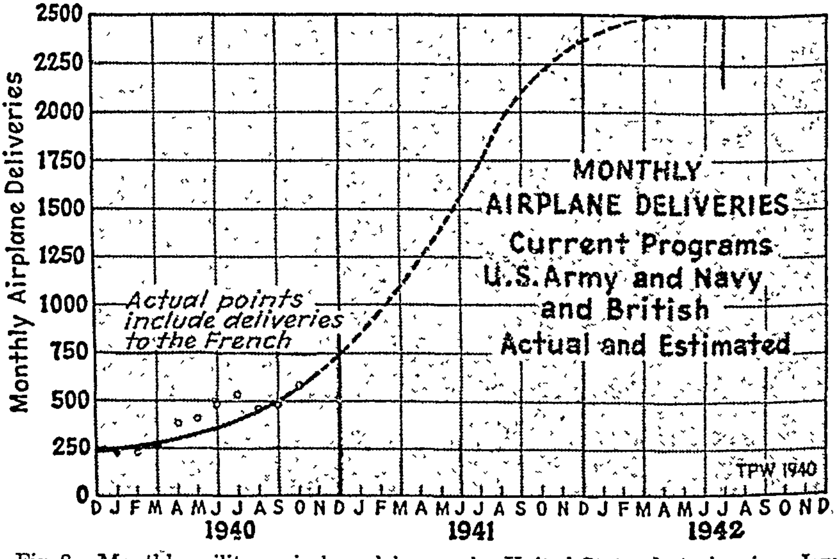


Fig. 8. Monthly military airplane deliveries by United States factories since January, 1940, and estimated future production.

Marketing Airplanes and Engines

Engines are sold only to manufacturers for original equipment to be installed in planes or to owners of planes—governmental, commercial, or private—for replacement purposes. High-grade men, combining the functions of engineer and salesman, usually are employed by each engine manufacturer to make sales to airplane manufacturers. Because of design difficulties, plane owners rarely specify for replacement an engine other than the one originally installed. Consequently, such sales are more or less automatic, and little effort is expended in making them. Replacement engine sales are made either direct from the factory or through the manufacturer's service stations, which may be independent, fixed-base operators or company-owned branches.

Engine trade-in and service problems. The trade-in problem on used engines does not exist, since an engine that requires replacement is useless as a resale item, and engine manufacturers refuse to make any allowance. Service policies vary; some manufacturers have the liberal belief that so much yet remains to be learned of aircraft engines that a rigid policy is unwise, while others adhere strictly to the letter of the guarantee and refuse to allow free service unless it is proved beyond doubt that the manufacturer is at fault.

The domestic market. The three principal purchasers of airplanes in the domestic market are the Federal Government, transport lines running on regular schedules, and so-called "commercial" purchasers. The latter class consists of private individuals buying planes for pleasure flying; business firms not directly connected with the aviation industry that operate planes for the transportation of salesmen, executives, and merchandise, and for sales promotion; and fixed-base operators who run flying schools and sell aerial taxi, photography, and crop-dusting services. State and municipal governments also have purchased planes from time to time for such purposes as police and forest-fire patrols, but these purchases have not been important in the aggregate.

Sales to the Federal Government. Purchases by the Federal Government consist almost entirely of planes for the United States Army, Navy, and Marine Corps; for defense, attack, observation, and bombing; and for the transportation of officers and enlisted personnel. In nearly all cases, competitive bidding is employed, and awards are made to the company submitting the lowest bid, provided the type of planes of that company has been satisfactory in the past or the company's experimental plane of the model to be ordered has met the rigid tests imposed. In view of the existence of a national emergency and since time is of the essence, negotiated and fixed-fee cost contracts are being resorted to to expedite getting production under way and units delivered. Airplane manufacturers usually bid only on the planes themselves; engine manufacturers bid separately on the engines to be installed, and the engine manufacturer ships to the airplane manufacturer the engines with which the planes are to be equipped.

Sales to transport lines. Transport lines also purchase direct from manufacturers. After deciding upon the most suitable model, sometimes the direct result of a design competition among the interested manufacturers, an order is placed with the airplane manufacturer, who includes the price of the engine in the prices quoted. Some years ago, when air transport first began, selling this market was a simple affair, since most of the air-transport mileage in the United States was at that time operated by companies directly or indirectly connected with airplane and engine manufacturers. Legislation was subsequently enacted which completely divorced the manufacturing end of the industry from the air-transport operating phase.

Sales to the so-called commercial market. The so-called commercial market has within recent years received most of the attention of the aircraft industry, but has contributed the least in profits, if not in unit sales In the following table it has been impossible to segregate clearly commercial planes produced primarily for air-line use from those used for other purposes, but it is clear that the former far outweigh the latter. The table gives a general picture of the relation between military and nonmilitary plane production within the last few years:

TABLE I

COMMERCIAL AND MILITARY AIRPLANE PRODUCTION FROM 1927 TO 1938[2]

Year	*Commercial Airplane Production*	*Military Airplane Production*
1927	1,565	621
1928	3,542	1,219
1929	5,357	677
1930	1,937	747
1931	1,582	612
1932	549	593
1933	591	466
1934	2,048	688
1935	1,974	991
1936	1,559	1,141
1937	2,281	949
1938	1,628	1,200

In general, sales to the commercial market have been made through distributors and dealers, or through dealers appointed direct from the factory. In most cases, distributors and dealers are independent and individually owned companies, but one large manufacturer owns a number of bases scattered throughout the United States which sell planes, service planes, and engines, and carry on fixed-base operations. Discounts to dealers purchasing through distributors vary between 5 per cent and 20 per cent of the list price, and the discounts granted to dis-

[2] Source: United States Aeronautical Chamber of Commerce.

tributors and direct factory dealers range between 10 per cent and 30 per cent. Manufacturers usually maintain traveling salesmen, who appoint new dealers, supervise the activities of existing ones, and help them to sell to their prospects. So far, distributing systems for aircraft have been embryonic, and control over outlets and prices usually has not been strict. The majority of manufacturers have sought to obtain as large a representation as possible, and airplane dealers may sell as many as six makes of planes, although, as a rule, the planes are non-competing models.

The airplane dealer. The typical airplane dealer or distributor is a fixed-base operator, maintaining a hangar and an office at a flying field; equipped to give at least light service to planes and engines; having a personnel of two or three pilots, one or two mechanics, and a stenographer; and carrying on flight training, taxi, and other aerial activities. In almost all instances, the airplane dealer obtains but a small proportion of his total income from the sale of airplanes; the major and profitable portion comes from operating a flying field and its related activities, which include the sale of gasoline, oil, accessories, and service. Low discounts and a highly restricted market in the sale of planes at retail account for this situation.

Fixed-base operators. In 1930, there were approximately 600 fixed-base operators in the United States, practically all of whom also sold airplanes. These operators maintained 5,324 planes in service; 763 licensed and identified planes were held in the names of transport lines, and 1,146 in the names of manufacturers. Only the remaining 2,865 of the total 10,098 can be presumed to be privately owned airplanes.

It is clear from these figures that the private user of an airplane is of relatively minor importance in the sale of airplanes and that the largest market for commercial planes has been among fixed-base operators, who also have been the manufacturer's distributors. In effect, then, discounts granted to distributors and dealers enable them to purchase their operating equipment at a lower price than they could otherwise obtain, and the use of their discounts as compensation for the expense of selling to the private owner has not been important. In other words, the market is an industrial one, and the major portion of the commercial planes sold are sold to those who operate them for profit. In spite of this condition, the marketing organization of the average commercial airplane manufacturer is designed primarily to sell to the private owner.[3]

Capacity demand; then decline. Following the spectacular long-distance flights of 1927, a tremendous increase in the demand for commercial airplanes arose. In few instances, however, was this demand from private owners; most purchasers were fixed-base operators who had been flying obsolete equipment or who had decided to start in busi-

[3] It is interesting to recall that, in the early days of the automobile industry, a manufacturer would grant the factory discount to almost anyone in a city where he was without representation, in order to obtain an outlet. Many purchasers represented themselves as dealers merely to buy a car for less than its list price.

ness to meet the increased demand for short flights from established airports. Consequently, there was an actual shortage of commercial airplanes during 1927 and 1928, and manufacturers were working at capacity. Capacity production continued through the summer of 1929, but production had caught up with demand in the spring of that year. As a result, the industry completed the year with a large surplus of airplanes held in inventory, and the downward turn in business conditions, with its resulting reduction in demand, forced into bankruptcy many of the small manufacturers who had started in business in anticipation of a constantly increasing demand over a period of years. Price cutting was undertaken to dispose of the bankrupt stocks and of the surplus stocks of solvent companies.

Price reductions. At the same time, several prominent manufacturers became convinced that the unwillingness of the general public to purchase airplanes for private use was the result of high retail prices. They believed that, by making drastic price reductions on airplanes, a large increase in demand could be fostered, and that the increased demand would make possible production economies which eventually would enable them to manufacture at a profit under the new scale of prices.

In 1930, the pressure of these two circumstances forced prices from 3 5 per cent to 43.2 per cent below those of 1929 for the same models of planes. The price war was participated in by 19 manufacturers, including nearly all the companies of first importance. The result, however, was not that expected Few sales were made to those who would not otherwise have purchased planes, and the general result was the sale of planes at a lower price to those who would have purchased them at the original quotation. At the same time, the production and sales of commercial airplanes fell off sharply.

Light planes introduced to stimulate sales. An experiment analogous to that of lower prices was undertaken by a number of manufacturers early in 1931, when so-called "light planes"—or airplanes with a seating capacity of one or two and engines of 30 to 50 horsepower, with a corresponding reduction in performance—were placed on the market. The result was the same as that of the widespread reduction in prices: few new purchasers were reached, and probably less money was brought into the industry than would have been the case with fewer unit sales but higher unit prices. Commercial airplane production declined from 5,357 in 1929 to 1,582 in 1931; sales declined from approximately 4,200 units in 1929 to approximately 1,600 in 1931.

A period of readjustment. As may be seen from the above figures, the commercial aircraft industry went through a period of readjustment. In 1929, it was widely believed that its development would be similar to that of the automobile; that belief changed to a better-founded one that the developments of the immediate future, at least, will be built around regular transport-line services. In short, flying an airplane still is, on the whole, a professional undertaking. The purchase of airplanes in large numbers by the general public will come only gradually.

The used plane trade-in problem. The trade-in problem is as acute in the aviation industry as it is in the automobile industry. Airplanes have been found to be far more durable than was at first expected; and this, together with the industry's inability to expand the market satisfactorily, has resulted in a request for a trade-in allowance by the great majority of purchasers. No concerted action has been taken to solve the problem, but a number of manufacturers recommend allowing only the price for which the plane can be sold, and accepting no trade-in until the salesman or dealer has found a purchaser for the used plane

Transporting the purchased plane. New planes usually are flown from the factory to the airport nearest the purchaser, and prices are quoted at list plus the cost of such ferrying, or fly-away-field.

Export trade. Airplanes and engines for export usually are sold through foreign representatives of the manufacturers. These representatives may or may not be interested in other branches of the aviation industry; in many cases, they are important merchants who have connections with the government and civilians of their country. Occasionally, a manufacturer in the United States has organized a sales tour, during which several planes fly through a number of countries giving demonstrations to interested parties and taking orders. A third method —not, strictly speaking, exportation—is to grant to foreign manufacturers licenses to manufacture and sell airplanes and engines, with the foreign manufacturers taking the entire responsibility for sales. Several large airplane and engine manufacturing companies maintain subsidiaries to handle the details of export sales and to supervise the activities of foreign representatives; in a few instances, these companies have established factories outside the United States.

Methods of Financing

Such pioneer builders of aircraft and engines as Curtiss and Wright depended for their capital on private sources. They started with a small personal investment and financed further manufacture from the proceeds of sales. This form of financing continued through the First World War; although a tremendous expansion in production took place to fill war orders, most of the capital was furnished privately, and few public issues of stock were made. In the years immediately following the war, the aviation industry collapsed, orders were negligible, and only scattered private individuals had the faith to provide capital to meet the crisis and keep the few remaining companies operating

After the long-distance flights of 1927, the situation changed radically. Public enthusiasm for aviation was transformed into a public desire to purchase aviation stocks of any sort whatsoever. This was accomplished, by means of the propaganda of investment bankers and other stock promoters, legitimate and illegitimate, and by judicious references to the large fortunes of Ford and other pioneers in the automotive industry. Such phrases as "the greatest industry the world has ever known" and "Keep some . . . stock in your safe-deposit box, and

when you get old it will keep you" added to the excitable public psychology accompanying a boom in the stock market and resulted in the distribution far and wide of aviation stocks, few of which held any prospect of appreciating in value or paying dividends then or in the future. The market value of aviation stocks on October 1, 1929, was more than $1,000,000,000.

Along with this influx of capital, nearly all of the airplane manufacturing companies required their retail outlets to sign contracts guaranteeing acceptance of a specified number of airplanes annually. As evidence of good faith, such dealers were asked to place deposits of from 5 to 15 per cent of the retail value of their commitments with the manufacturer. Fortunately, this was not the most important method of financing manufacturers, as it was in the automobile industry. Nearly invariably, dealers overcommitted themselves, either because of undue optimism or because of a desire to impress the manufacturer. When it was at last discovered that the private market for airplanes was distinctly limited and the dealers' deposits were nominally forfeited because of inability to sell their quotas, manufacturers were faced with a choice between retaining the deposits and forcing dealers into bankruptcy or returning them. As a rule, the latter procedure was followed, since the average manufacturer had obtained a plethora of capital from other sources, and he was wise enough to see the necessity of protecting his contacts with whatever market existed.

Whether this deluge of capital was fortunate or not is an open question. Certainly it gave an opportunity for expansion on a scale not otherwise possible. But just as certainly, it went to the heads of many companies, and resulted in unwise and wasteful policies; and public faith received a jolt in proportion to the tremendous losses sustained through security depreciation. Paradoxically, the aviation industry once more has its feet on the ground. Retrenchments are replacing extravagance, and the days of glory have been superseded by the days of well-considered business policies.

Important Legislation Affecting the Industry

The Kelly Bill. On February 2, 1925, President Coolidge signed the Kelly Bill, authorizing the Postmaster General to contract with private organizations to carry United States mail by air. Thus the way was opened for the present highly developed system of commercial air transportation in this country. Before the passing of this bill, air-mail operations had been carried on by the Post Office Department itself; within a short time, private operators exclusively were carrying the air mail.

The Air Commerce Act. The next important legislative step was taken when the Air Commerce Act of 1926 became law. Prior to this time, there had been no body of Federal law designed to regulate air commerce; and while the absence of regulation may have had desirable effects in giving a free hand to pioneer operators and builders, there was no assurance of continued Government support, and no assurance to

the general public that planes were safe and subject to strict performance requirements.

The National Advisory Committee for Aeronautics summarized the Air Commerce Act as follows:

> This Act provides the legislative cornerstone for the development of commercial aviation in America. It establishes certain fundamental principles to govern the relation of the Federal Government to the whole problem of aiding the development of commercial aviation in America on a sound basis. The Act asserts the doctrine of Federal sovereignty in the air over the lands and waters of the United States to the exclusion of foreign nations. It asserts under the commerce clause of the Constitution the right of the Federal Government to regulate interstate air commerce. It authorizes the designation of airways by the Federal Government and compels adherence to a single set of Federal flying rules on the part of all who use such airways, regardless of whether they are engaged in interstate or intrastate air commerce or private flying. It authorizes Federal lighting systems along airways and the Federal establishment and maintenance of emergency landing fields. It authorizes the transfer of the postal airways, including emergency landing fields, to the jurisdiction of the Department of Commerce and the transfer of the postal airports or terminal facilities to the jurisdiction of the municipalities concerned under arrangements subject to approval by the President. It contemplates the establishment and maintenance of airports by the municipalities or by private industries. It provides for the compulsory registration of aircraft engaged in interstate commerce and for the optional registration of other aircraft. It provides for the periodic examination and rating of airmen serving in connection with registered aircraft. It provides for the emergency use of existing governmental facilities, extends the application of existing laws to foreign air traffic, and, in short, imposes upon the administrative officer concerned—the Secretary of Commerce—the duty of fostering the development of air commerce in the United States.

The bill also provided for the appointment of an Assistant Secretary of Commerce for Aeronautics, to have charge of the Aeronautics Branch of the Department of Commerce

In the same year, Army and Navy 5-year aviation programs were adopted providing definite programs for the expansion of the military branches of aviation.

The McNary-Watres Act. This act, approved on April 29, 1930, was the next important legislative enactment. Before the passage of the act, air-mail contracts had been granted on competitive bids per pound of mail carried, regardless of distance Under this system, many short lines had secured contracts at the maximum rate of $3.00 per pound, while lines hundreds of miles longer might carry the mail at a rate less than half as high. The McNary-Watres Act provided for a more equitable basis, in that payments were made on a space-weight per mile rate Payments also were so scaled as to encourage the carriage of passengers in large planes along with the mail, and recognition

was given to those companies that had been foremost in pioneering passenger operations.

Creation of Civil Aeronautics Authority. In August, 1938, regulation of civil aviation in the United States was removed from the jurisdiction of the Department of Commerce and vested in the Civil Aeronautics Authority, a five-man board created by the Civil Aeronautics Act and appointed by the President, with the advice and consent of the Senate.

Earnestly sought by the aviation industry, which went to Congress and asked for a tribunal before which it could settle its problems and for an agency through which its relations with the Government might flow in a single stream, and strongly recommended by the President, the Civil Aeronautics Act was the culmination of long-continued efforts by members of Congress, the Administration, the industry itself, and private citizens interested in the future of aviation. Its passage was hailed as giving a new organic charter to Civil Aeronautics in the United States, framed in the light of existing conditions as well as with an eye to the future.

In 1940, as a result of actual experience under the operation of the Civil Aeronautics Act, there was a further reorganization, transferring the functions of the administrator back to the Department of Commerce, changing the name of the body to "Civil Aeronautics Board," and also effecting certain internal changes within the organization and relegating its authority and functions to various divisions of the new Civil Aeronautics Board. Final setup has not yet been arrived at, and there is considerable agitation at the present writing among members of the legislature in Washington, and also within a portion of the industry itself, calling for a further reorganization and restoration of the status of the group regulating civil aviation in the United States as an independent body.

Development of Transport Aviation

Statistics tell the story of the growth of regularly scheduled air-line services more dramatically than words could do. It is one of practically uninterrupted progress since May, 1918, when operations on a regularly scheduled basis were first undertaken. For the year 1920, records of the Post Office Department indicate that 864,128 miles of operations were flown, carrying 441,742 pounds of mail and 41,390 pounds of express. Passengers were not carried on a scheduled operations basis until 1926, when the total for the year was just under 6,000 persons. Table II summarizes the growth of air-line operations and traffic during the past decade.

Going from an original appropriation for Government operation of air mail, in 1918, of $100,000.00, there was paid to air-mail contractors for the fiscal year 1938 the sum of $14,182,243.

One of the reasons for the astounding growth of the air-transport system of the United States has been the remarkable safety record that

TABLE II

DOMESTIC AIR LINES IN THE UNITED STATES FROM 1931 TO 1939

Year	*Miles Flown*	*Number of Passengers*	*Passenger Miles*	*Mail*	*Express*
1931	43,395,478	457,753	116,232,153	9,351,195	885,164
1932	48,334,358	504,575	143,168,682	7,658,332	1,324,428
1933	50,800,705	546,235	183,695,784	7,664,646	1,884,545
1934	42,622,619	537,637	217,096,507	7,155,281	2,946,460
1935	59,534,013	908,185	360,267,931	13,538,952	6,162,056
1936	63,777,226	1,020,931	435,740,253	11,482,872,623[4]	6,985,777
1937	66,190,639	1,102,707	476,603,165	13,396,460,117	7,127,369
1938	69,668,827	1,343,427	557,719,268	14,845,719,671	7,335,967
1939	82,571,523	1,876,051	749,787,096	17,170,021,595	9,514,299

they have set in their operations. For the 12 months ending March 26, 1940, the air lines of the United States flew 87,325,145 miles, transporting 2,028,817 passengers without a single fatal accident.

The principal problem remaining to be solved by the air lines is one of convenience. At present, a number of large cities are served by airports so distant from the business sections that little time is saved on short runs, even with the extremely high speed of the modern transport plane. With greater distances, the time involved in going to and from airports is less important; but the inconvenience of reaching airports,

TABLE III

DOMESTIC ACCIDENT STATISTICS FOR YEARLY PERIODS AS INDICATED

	12 Months Ending March 26, 1938	*12 Months Ending March 26, 1939*	*12 Months Ending March 26, 1940*
Total Miles Flown	67,002,154	71,080,308	87,325,145
Total Passengers Carried	1,157,738	1,389,818	2,028,817
Total Passenger Miles	503,484,761	565,220,938	814,906,250
Fatal Accidents	4	5	0
Fatal Passenger Accidents	4	5	0
Passenger Fatalities	32	20	0
Crew Fatalities	10	8	0
Miles Flown Per Fatal:			
Accident	16,750,539	14,216,062	—
Passenger Accident	16,750,539	14,216,062	—
Passenger Fatality	15,733,899	28,261,047	—
Crew fatality	6,700,215	8,885,039	—

[4] Commencing with 1936, the Post Office Department discontinued the practice of issuing mail-poundage figures, owing to a change in their operations whereby reimbursement to air carriers was placed on the basis of pound-miles of operation.

compared with the ease of reaching the midcity location of most railroad terminals, is still a deterrent factor. That this is recognized and is being studied by air-transport operators may be indicated by recent experimental operations of one of the leading air-line passenger and mail operators wherein air mail, upon arrival at the air terminal of a large Eastern city, was immediately transferred to an autogiro, which, taking off from the airport, flew into the metropolis and landed on the roof of the main post office in the heart of the city.

The dependability of flying equipment has been supplemented by blind-flying instruments and constant radio communication with the ground to pick up weather reports on the route ahead.

Possible Future Developments

The roseate predictions made for private flying by the general public, which were so characteristic of the boom period lasting through the summer of 1929, died a natural death in the light of subsequent experience; but all that has been predicted for the growth of scheduled air-line services has been fulfilled. It has become apparent that the development of scheduled service must precede any wide development of private flying, for, insofar as the average man is concerned, the privately owned airplane is far from being indispensable and still is handicapped by danger and inconvenience. The high cost of flying is another difficulty, but one of less importance. Widespread adoption must depend upon the creation of a machine that will overcome these difficulties, and such development may involve radical departures from anything we know today.

Probability of express and freight transportation. It is probable that the next development of importance in air-line service will be the institution of express and freight transportation on a large scale and at reasonably low rates. To date, this source of revenue has been neglected, except for a few attempts on the part of scattered operators; but many air-line executives realize that revenue from the transportation of merchandise has been the railroads' chief source of profit, and they believe that there is no important reason why it should not, in the future, become the financial backbone of air-line operations. Important difficulties so far have been those of gaining sufficient volume to make possible low rates that still return a profit, and of developing an adequate ground organization and pick-up and delivery service. It is evident that large capital resources must be obtained before widespread services of this character can be established, because of the necessity of breaking the circle of low volume, low utilization of plane capacity, high operating costs, high rates, low volume, etc. Another difficulty is that plane operation must be in units, and large volume means adding more units without a comparative reduction in cost. The railroad merely adds extra cars to a train with little additional expense; the air line must add new planes.

Transoceanic air-mail and passenger service. Long the dream of the so-called "visionaries" of the industry, first trans-Pacific and then trans-

Atlantic air-mail and passenger service have become realities within the past decade. It is difficult to realize that, only 14 years after Lindbergh's solo flight over the Atlantic—and that which was considered almost a miracle in its day—large flying clippers are taking off on a several times a week schedule from New York and San Francisco, and wending their respective ways over the Atlantic and Pacific, loaded with mail, express, and—most remarkable of all—passengers.

Transoceanic air-mail service was just getting into its stride when the outbreak of hostilities of the Second World War seriously upset normal operations and growth. Although the service has not been entirely abandoned, it is being continued under difficulties. Owing to the lack and hazard of surface shipping, transoceanic air service is being found somewhat of a boon for the safe transport of mail and the few highly important individuals who are crossing the oceans in these troubled times

Development of larger planes. Enlargement of the size of air transports to meet the ever-increasing air traffic has been underway for some years, and there are currently flying 4-engined air transports capable of transporting 40 to 50 passengers, with an additional load of mail, express, and baggage, on a nonstop flight from New York to California in from 16 to 17 hours, or just overnight.

Further development of passenger transports must unfortunately await the coming of peace to the world once more, although, making the best of necessity, it will not be surprising to find that lessons learned in the hurried development of larger and even larger military bombardment airplanes and troop and cargo carriers will later be found of direct benefit in carrying on the real mission of the airplane, namely, the transportation of people and goods along the commercial airways of peace.

Increasing mail, passenger, and express revenues will change the direct revenue picture, but the relation of air transport to national defense, airport expense, competition with completely Government-subsidized air services of foreign countries, and other factors will still necessitate some form of assistance to United States air-transport industry.

Travel and Speed Records

Circling the globe. The early records for circling the globe make an interesting comparison with those of today. Del Cano (1522) circled the globe in 3 years, establishing probably the first record. Drake (1577) and Cavendish (1586) accomplished the same feat, but neither lowered the record much. The next important record of 72 days was set in 1889 by Elizabeth Cochrane. This was lowered to 67 days by Train, in 1890; to 60 days by Fitzmaurice, in 1901; and to 35 days by Mears, in 1913 In 1926, Evans and Wells, using airplanes and ships, lowered the record to 28 days. In 1927, a new record of 23 days, 15 hours, and 21 minutes was set by Mears and Collyer.

The first lighter-than-air record of 21 days, 7 hours, and 24 minutes was established by the *Graf Zeppelin* in 1929. In 1931, Post and Gatty set a heavier-than-air record of 8 days, 15 hours, 21 minutes. In 1933,

Wiley Post made his solo flight in 7 days, 18 hours, 50 minutes. Thereafter, almost each year saw a new record set, until in July, 1938, Howard Hughes and a crew of four, flying a Lockheed Monoplane powered by two 1,100 H. P. Wright cyclone engines, set the present record of 3 days, 19 hours, 8 minutes.

Transcontinental flying. Transcontinental air records have been set and broken with almost yearly regularity. The first dusk-to-dawn *flight was made by R. I. Maughan on June 23, 1924, in 21 hours, 48* minutes, 30 seconds. Many other outstanding pilots made similar flights, each setting a new record, until on April 20, 1930, Colonel and Mrs. Lindbergh made the flight in 14 hours, 23 minutes, 27 seconds. Ruth Nichols, on December 10, 1930, lowered the record to 13 hours, 21 minutes, 43 seconds; Major J. H. Doolittle, on September 4, 1931, to 11 hours, 15 minutes; Major R. Turner, on September 24, 1933, to 10 hours, 5 minutes, 30 seconds; and Howard Hughes, on January 14, 1936, to 9 hours, 27 minutes, 10 seconds. On February 11, 1939, H. Ben S. Kelsey, of the United States Air Corps, set a new transcontinental record of 7 hours and 45 minutes.

33

The Telegraph Industry

Early History of the Telegraph

Early methods of signaling. Few great inventions which have speeded the world's progress are the product of one man's work, and the telegraph is no exception to the rule. Literally hundreds of men may be said to have made contributions over a period of centuries to the world's knowledge of magnetism, electricity, and communication by wire before Samuel F. B. Morse brought forth the first practical recording telegraph instrument, which provided the basis for the creation of the present world-wide network of telegraphs—the nerve system of world commerce and trade and social correspondence.

Man has sought to overcome distance in his communications since the days when savage tribes roamed the forests. First there were runners, and later horsemen; then signals by fires on towers and hills, and by the tooting of horns. In America, the Indians signaled by a code of short and long puffs of smoke from fires covered by blankets. In Africa, savages beat tom toms to summon tribal warriors. About 150 years ago, the French began using semaphores on hilltops, moving the crossarms of semaphore towers to convey messages

Early knowledge of lodestone. The Chinese knew of the lodestone, or natural magnet, about 2600 B.C., and their navigators were using the magnetic compass centuries before it was known in Europe Some 2,200 years ago the Greeks played with amber beads, which became electrified when rubbed and would pick up thread. It was not until Roger Bacon published his theories on the lodestone in 1267, however, that thought was directed to using this force for communication.

Early inventions. In 1558, Porta wrote of two needle-shaped pieces of steel mounted on dials with letters around their margins. These needles were magnetized by the same lodestone; and when one needle was turned, the other was supposed to move "sympathetically" to the same letter, thus making communication over a distance possible. Wood, of England, discovered in 1726 that static electricity could be conveyed by pieces of metal, and others were soon experimenting with static discharges through lengths of wire. Musschenbroek, who invented the Leyden jar, in which electricity could be stored, found in 1754 that the

electricity in the jar could be conveyed a distance by means of a wire. Galvani discovered galvanic activity in 1786.

The first practical suggestion of telegraphy was made about 1747 by a Scot known only as "C. M." He advised using a separate wire for each letter of the alphabet Le Sage in Geneva carried out the idea, and he was followed by others. Reizen, Salva, and Ronalds created visible telegraphs. The latter, in 1823, operated in England a system by which a disc at each end of a single wire revolved slowly, so that the same letter on each disc would appear at the same time and a signal was sent as each desired letter appeared. Harrison G. Dyar on Long Island, in 1826, built a 2-mile telegraph system operated by causing a spark discharge which discolored a moving strip of litmus paper

Building upon various other discoveries, Sturgeon invented in England, in 1825, an electromagnet, which Joseph Henry, a professor at Albany, New York, improved and used in 1829 in a signaling apparatus to sound a bell for which a code was devised. In 1819, Oersted discovered the deflecting influence of current on a magnet needle.

Ampere, in 1820, adopted Laplace's suggestion that small magnets be used at the ends of 26 wires to indicate the letters of the alphabet, and he was followed by other inventors who used magnets to cause needles to swing to the right or left upon receiving pulsations over the wire and thus to convey signals. Important among these were Cook and Wheatstone, who, on December 12, 1837, applied for a patent for a telegraph that used galvanometer needles and operated over moderate distances. In the same year, Steinheil placed in operation an electromagnetic-needle telegraph connecting the observatory and the Cabinet of Natural Philosophy at Göttingen. Three months earlier than Steinheil, Morse published his invention.

The first practical telegraph instrument. It was Morse, then, who presented the first practical instrument for recording signals over the wire. When the small ship *Sully* sailed from Havre on October 1, 1832, for New York, none of those on board, and least of all Morse, a distinguished American painter and president of the National Academy of Design, dreamed that the trip would result in an invention that would annihilate distance in communication.

Among the group of influential Americans on board was Dr. Charles T. Jackson, of Boston, who discoursed at the dinner table of the then recent discoveries in electromagnetism and the length of wire in the coil of a magnet.

"Was the velocity of electricity retarded by the length of the wire?" someone asked. Dr. Jackson replied that experiments had shown electricity passes instantaneously over any length of wire.

"If the presence of electricity can be made visible in any part of the circuit, I see no reason why intelligence may not be transmitted instantaneously by electricity," Morse exclaimed. He left the table and went on deck, his mind filled with a great inspiration.

He first thought of signs that could be transmitted over the wire, and realized that the dot, the dash, and space were three signs which could be

sent. He jotted down a dot and a dash code for numbers. He also sketched a receiving instrument—practically the same as the Morse telegraph instrument which is still used to a limited extent today. The weak permanent magnet has been replaced by a spring and some other minor changes have been made, but an electromagnet still attracts the lever and produces dots and dashes as the original drawing indicates.

Morse worked incessantly and had developed his idea to such an extent that, before the vessel arrived at New York, he told the captain:

"Well, captain, should you hear of the telegraph, one of these days, as the wonder of the world, remember the discovery was made on board the good ship *Sully*."

Morse could not devote all of his time during the next 3 years to the construction of telegraph apparatus because, in order to live, he had to paint and to teach painting. He lived in a garret and made models by hand in his spare hours.

During the birth of his invention, Morse was often near starvation. Once he asked a wealthy young Virginian for the weekly tuition due for his art lessons. The pupil said the post had not brought his allowance but that it no doubt would the next week.

"Next week!" Morse exclaimed. "I shall be dead by that time."

"Dead, sir?"

"Yes, dead by starvation."

In 1835 he was appointed Professor of the Literature of the Arts of Design at New York University. This appointment gave him a small salary and rooms in Washington Square, where he could live and work. In these rooms, he built the first telegraph instrument—a crude affair on a picture frame, with an ordinary lead pencil suspended by a pendulum to make the dots and dashes.

After Morse had completed the first instrument, friends and scientists came to his rooms in Washington Square, saw the invention work, and acclaimed it. Finally, Alfred Vail came to see the invention and became an enthusiastic supporter. Vail obtained the aid of his father, a manufacturer at Morristown, New Jersey, and at that plant apparatus was built in the fall and winter of 1837 and public demonstrations were begun in January, 1838.

Morse then turned to Congress to finance the construction of a telegraph line. For 6 years he struggled to convince Congress and the nation, with little success. On the closing day of Congress, in 1843, Morse sat in the gallery until nearly midnight waiting for his bill to come up, and went back to his hotel in bitter disappointment. The next morning Miss Annie Ellsworth, daughter of the United States Commissioner of Patents, congratulated Morse upon his success, informing the astonished inventor that the Senate had passed the Telegraph Bill in its closing minutes, thus making available $30,000 for the construction of a telegraph line.

With this money, Morse, Vail, and Ezra Cornell built the first telegraph line between Washington and Baltimore. On May 24, 1844, in the presence of many notables, Morse sent the first public message:

"What hath God wrought?" dictated by Miss Ellsworth. Vail, at Baltimore, sent it back. It was, therefore, 12 years after Morse's trip on the *Sully* before he sent the first public telegraph message

First practical use. Since the fundamental idea of society is that of intercommunication, use of the telegraph began almost simultaneously with its operation At first, the use was almost entirely practical and even of an emergency nature.

Two days after the first public message was sent, the National Democratic Convention at Baltimore nominated James K. Polk for president and Silas Wright for vice-president. Vail sent the news to Morse at Washington, 40 miles away, and the latter informed Wright, who immediately wired back his refusal to run. The delegates were dubious as to the authenticity of the reply, which was received within a few minutes of the nomination. They adjourned and sent a committee to Washington to confer with Mr. Wright before they would accept his answer.

Difficulties Morse encountered. At the very outset, people questioned Morse's sanity and were unwilling to believe the then almost incredible fact that intelligence could be sent instantly to a distant point. Then, when repeated instances of its use became known and the public began to believe in the basic fact of telegraphy, the invention was still regarded as a mere toy and of little use, and men refused to rely upon it in matters of importance. Even the Government did not believe the telegraph would ever pay revenues sufficient to carry the cost of maintaining the line. It withdrew financial support after contributing $8,000 to the operation for a year. The tariff instituted was 1 cent for every four characters. Revenue was extremely small. Morse and his associates, in 1845, sought to sell the telegraph to the Government for $100,000, but the offer was refused. As a result of this refusal, the telegraph in the United States was developed by private ownership and capital, and far outstripped in size, volume, and speed of service the telegraphs of other nations, where governmental ownership and operation were the rule.

Morse at once began raising $15,000 for construction of a line between New York and Philadelphia. Capitalists refused to be attracted, but people of moderate means came to the rescue. The Magnetic Telegraph Company was the first incorporated telegraph company. Under the superintendence of Ezra Cornell, it completed its line from Philadelphia to Fort Lee on January 20, 1846, and extended it to Baltimore in the same year, joining with the line to Washington.

At the same time, other similar inventions and devices found their supporters, and other companies were organized which began building short telegraph lines. A chaos of conflicting claims resulted, which was followed by years of litigation over patent rights and in which Morse finally triumphed.

The unwillingness of the public to rely upon the telegraph is illustrated by the fact that it was not until the autumn of 1851 that the first telegraphic train order was sent, and not until some years later that telegraphy was used generally in the operation of railroads. The first train dispatch by telegraph is credited to Charles Minot, general superin-

tendent of the Erie Railroad. A westbound express train reached Turner, New York, and the eastbound train had not arrived. Mr. Minot wired to the next stop, ordered the eastbound train held if it arrived, and ordered the engineer to proceed. The engineer refused, so Mr. Minot took the throttle and ran the train himself.

After that time, the development of the telegraph was largely along the right of ways of railroads. The first line was along the Baltimore and Ohio Railroad, between Baltimore and Washington, D. C. Now most of the miles of telegraph-pole lines follow railroads, and telegraph offices are to be found in railroad stations in all parts of the nation.

First cable system. Few romances in business equal that of the submarine cable. The story of man's struggle to establish communications across the water is even more dramatic than that of the years of poverty and struggle of the telegraph pioneers.

Today, when there are 3,000 submarine cables with a total length of 360,000 nautical miles, and the bottom of every ocean carries these busy threads of world communication, it is difficult to realize that, within the memory of living man, there was not one ocean cable and that transmission of intelligence across the sea was not a matter of seconds but of weeks.

People in Battery Park, at the tip of Manhattan Island, on the night of October 18, 1842, were astonished by the appearance of a man in a rowboat, with one assistant, laying a cable to Governor's Island in New York Harbor. It was agreed by the observers that the man must be crazy. That man was Morse, inventor of the telegraph, pioneering in cable experimentation also.

On the next morning, Morse was exchanging signals over his 2 miles of insulated wire when the cable suddenly failed. A vessel raising its anchor in the harbor had fouled the cable, and the sailors, not knowing what it was, cut off 200 feet of it as a souvenir and sailed away.

Morse repeated his experiment at Washington the next year, and in a letter to the Secretary of the Treasury, dated December 23, 1844, he proposed the establishment of communication between America and Europe Because he was busy with the telegraph, however, he did not carry his cable experiments further.

The honor of establishing the first submarine cable in practical use has been claimed for Samuel Colt, inventor of the revolver. Colt invented a battery for submarine harbor defense and, in 1843, laid a submarine telegraph cable in New York Harbor. He extended this cable from the Merchants' Exchange in New York City to Fire Island and Coney Island, to obtain early marine news.

Ezra Cornell, whose association with early telegraph construction was described above, laid a 12-mile cable between Fort Lee and New York City, across and down the Hudson River, in November, 1845, for use in conjunction with the first telegraph line from Philadelphia to New York, which was completed to Fort Lee, January 20, 1846. The cable was carried away by ice in 1846, and messages were carried across by boat until

high masts were erected and an overhead wire was stretched across the river.

It was on August 28, 1850, 8 years after Morse's experiment in the New York Harbor, that the first European cable was laid. It connected Dover, England, and Cape Griz Nez, France. That cable developed defects in a short time and was later put entirely out of use by a French fisherman, who hooked it and cut away a part, thinking it a strange seaweed. The Gutta Percha Company of London, which made the first cable, manufactured another in 1851 with iron-wire sheathing and hemp wrappings, as well as gutta percha. This cable was successful and was followed in the next few years by other short cables in European waters.

F. N. Gisborne saw that the time of communications between Europe and America could be reduced by several days by extending telegraph lines to St. Johns, Newfoundland, the last stop for ships bound for Europe and the first for ships coming to the United States. At first he failed; then he met Cyrus W. Field, a retired businessman, who not only accepted his idea but suggested the extension of the proposed line across the Atlantic Ocean and obtained financial backing.

The land line was first extended to the coast of Nova Scotia and then, by means of an overhead wire suspended from towers, across the Strait of Canso. It was carried by land line to the northern extremity of Cape Breton Island. From that point, at Aspy Bay, a cable was laid to Port au Basque, Newfoundland, to connect with a land line 400 miles across Newfoundland to the east coast.

A tablet commemorating the laying of the cable from Aspy Bay to Port au Basque was unveiled in the Western Union cable office at North Sydney, Nova Scotia, on September 24, 1930. It bears the following inscription:

> First Atlantic Cable
>
> This tablet commemorates the first submarine cable in North America, laid in 1856 between Cape Breton and Newfoundland, the first stage in the development of cable communication between this continent and Europe.

The first attempt to lay a cable across the Atlantic was made on August 7, 1857, by the United States Navy Frigate *Niagara*, but, after 300 miles had been laid from Ireland, the cable snapped. The second attempt was begun on June 25, 1858, when the *Niagara* and H.M.S. *Agamemnon*, of the British Navy, met in mid-Atlantic; each spliced its section of cable to that of the other and started home, laying cable as it went. The cable broke, and 144 miles were lost. The ships met in mid-Atlantic, spliced cable again on July 29, 1858, and on August 5 the *Agamemnon* arrived at Valentia, Ireland, and the *Niagara* at Trinity Bay, Newfoundland.

There was rejoicing on both sides of the Atlantic. Among the first messages exchanged over the cable were congratulations between Queen Victoria and President Buchanan. On September 3, however, the cable became silent. It had carried only 400 messages, totaling 4,358 words.

A new company was formed, and a larger and stronger cable was built.

The largest steamship afloat, the *Great Eastern*, began laying this cable on July 23, 1865, but the cable snapped 1,186 miles out in 2,000 fathoms of water. The cable was raised repeatedly, but each time the grapnel lines broke, so the *Great Eastern* returned home.

Field and his associates refused to give up, and the *Great Eastern* again started out on Friday the thirteenth, July, 1866. This time the cable was laid successfully.

Three men were alive in 1931 to tell the historic story from their own memories. They were Captain William N. Napper, 92, of Lake Geneva, Wisconsin; Martin Cahoon, 89, of Onset, Massachusetts; and Captain Waldemar Peterson, 80, of Long Beach, California. The latter was a cabin boy, and his memory of dates and events is somewhat vague, but vivid stories have been told by Captain Napper, who was chief carpenter on the *Great Eastern* for 3 years, and Mr. Cahoon, who was an able seaman on the former queen of the seas

Both men lauded Field, who, Captain Napper declared, "knew no such word as fail." Mr. Cahoon emphasized Field's attention to every detail and his constant attendance in the testing room, where signals over the cable kept the *Great Eastern* in touch with Ireland. He recalled coming in contact with a live wire while helping in the test room one day and dancing helplessly until Field shut the current off. Captain Napper related the actual experience of laying the cable as follows:

> We tied the cable up at old Ireland and then began paying it out as we went along, in July, 1865 The cable was carried in three great tanks —one foreward, one amidships, and one aft—and submerged in water. Everything went fine until we were 1,200 miles out Then, in testing the cable, the engineers found something had gone wrong. The *Great Eastern* was turned around and the cable taken in. While doing this it broke, slipping back into the water That was a great disappointment to everybody. For four full weeks we grappled for the end, but without success, and finally gave it up for the time being.
>
> Starting out the next year, in 1866, we laid the second cable successfully to Trinity Bay, Newfoundland. What a celebration there was at Heart's Content!

That occasion also stood out in the memory of Mr. Cahoon. When the ship had almost reached Newfoundland, he remembered, the signals over the cable indicated a fault, and it required all day for the ship to turn around and pick up the cable and remedy the fault. During this period, he said, there was the greatest anxiety in England, where the cause of the sudden silence was not known.

Both Captain Napper and Mr. Cahoon remarked that those in charge did not pay the crew when they reached Heart's Content, so the crew would remain sober upon landing. But according to Captain Napper, "that didn't do any good, because everybody was in such a happy mood that brandy and beer flowed like water and was free to the crew. Strictly sober men were rare in those days, and they certainly had cause to celebrate."

The celebration was cut short, however, for the *Great Eastern* soon went back to mid-Atlantic and set about raising the end of the cable it

had laid to that point the year before, in July, 1865. Of this second venture, Mr. Cahoon related that, "after six hours of repeated grappling, the 1865 cable was raised to the surface, where it broke. The *Great Eastern* then sailed thirty miles east, raised the cable to within twenty feet of the surface, and sent down a diver to fasten a rope to it, for fear it might break again if pulled to the surface." Then the 1865 cable was continued to Heart's Content.

With two cables operating across the Atlantic, the Steamship *Medway*, which had assisted the *Great Eastern*, then laid a cable from Cape Ray, at the southwest corner of Newfoundland, to Cape North, at the northern extremity of Cape Breton, thus providing a cable connection with the land lines in Canada and the United States. These two Atlantic cables remained for some years the only means of high-speed communication between Europe and America.

Development of the Telegraph Industry

The beginnings of the telegraph as a system in the United States. Following the refusal of the United States Government to take over the ownership and operation of the telegraph, as proposed by Morse and his associates, a number of companies operating short telegraph lines were organized. Over 50 telegraph companies were in business in the United States in 1851, 7 years after the first public message was transmitted.

Almost all of these companies were licensed by owners of the Morse patents, but a few used other devices. One of these was an invention by Alexander Bain, which involved the use of a roller at each end of the telegraph line, each revolving clockwise at a regular speed. A paper ribbon was perforated with the desired dots and dashes at the sending end, and, as each perforation passed beneath a spring resting on the roller, the spring contacted with the charged roller and flashed a long or a short signal. At the receiving end a similar spring, dragging on a chemically treated ribbon of paper, conveyed the electricity to the paper and made a dot or a dash.

Another invention used by some lines was the House printing telegraph, important because it was the forerunner of automatic printing telegraphy, which today handles about 94 per cent of the nation's telegraph business. The machine, invented by Royal E. House, of Vermont, imprinted Roman characters by telegraph and thus eliminated the translation of words into dots and dashes and back into words again. The value of the House patent was recognized by several persons who organized companies to develop this method of operation.

In 1849 and 1850, lines were built to operate the House system between New York and Buffalo, New York and Boston, and New York and Philadelphia. On April 1, 1851, a group of Rochester men, led by Hiram Sibley, Ezra Cornell, and Samuel L. and Henry R. Selden, acquired rights to extend the House system throughout the United States and incorporated as the New York and Mississippi Valley Printing Telegraph Company.

This company constructed a line from Buffalo to Louisville but did not extend it to St. Louis, as planned, owing to the lack of stock subscriptions. The proposed capital stock of the company was $360,000, but it was impossible to sell more than $170,000. Although the company went into debt $15,000 in its first 3 years, it displayed its determination by purchasing the Lake Erie Telegraph Company lines from Buffalo to Detroit and from Cleveland to Pittsburgh in 1854.

The new company was in a far better condition than most of the 13 other companies operating in the 5 states north of the Ohio River, which suffered the disadvantages of multiple and inharmonious management, doubling rates when messages passed to other lines and rendering slow and unreliable service. Two of these lines were sold for debt, and the others were in such an impoverished condition that the principal owners approached the New York and Mississippi Valley Printing Telegraph Company in 1854 and 1855 with offers of sale

Western Union Telegraph Company. Through the coöperation of Ezra Cornell and some of the other principal owners of telegraph property in the north-central states, a consolidation was effected, and, by authority of an act of the New York State Legislature on April 4, 1856, the combined companies were given the name of the Western Union Telegraph Company, indicating the union of the "western" lines in one system With protection from competition, elimination of duplicated management, and freedom to use the simpler and more economical Morse devices, Western Union made great strides

In 1861, Western Union built the first transcontinental telegraph line, linking the Pacific Coast with the East by furnishing rapid communication across thousands of miles of Indian-infested desert and wilderness. In 1866, it absorbed the other two sizeable companies, the American Telegraph Company and the United States Telegraph Company, and moved its headquarters from Rochester to 145 Broadway, New York City. The company, which had started out with 550 miles of wire, then had 75,686 miles of wire and 2,250 offices.

Growth of the industry. Uniform and widespread service under responsible management, as contrasted with the previous poor service given by numerous small companies, was recognized and rewarded by the public; business multiplied. The formerly poor and struggling company became wealthy and constantly declared large cash and stock dividends which were well within its earnings.

By acquiring existing lines and constructing new and better lines, the company rapidly extended its operations over the country. After the transcontinental line had been completed, the telegraph companies of the Pacific Coast were federated and merged with the national system.

One of the Pacific Coast lines, built almost immediately after completion of the transcontinental line, extended from San Francisco to Oregon and Vancouver. It was then proposed by Perry MacDonough Collins, who had served as consul at St. Petersburg and also as American Commercial Agent at the mouth of the Amur River on the coast of Siberia, that the line be extended through British Columbia and Alaska, across

Behring Strait by short cable, and then southwest through Siberia to the mouth of the Amur River.

Collins had obtained an agreement that the Russian Government would build a line across Siberia from St. Petersburg and Moscow to meet the American line. He also had obtained a concession from the British Government for the right of way through British Columbia. He sold his concessions and grants on March 16, 1864, to the Western Union, which undertook the work, after despairing of the early laying of an Atlantic cable, a task which had been attempted so often without success.

A great expedition was organized, divided into British Columbia, Alaska (then Russian-American), and Siberia land parties, and a marine service with a fleet of vessels, and all sections were actively engaged by the end of 1865. The story of the hardships and adventures of these parties forms one of the most romantic chapters in telegraph history. Each surveyed its entire section; more than 1,000 miles of line were built; the cable was laid; and success seemed within grasp when, owing to the laying of the first successful Atlantic cable in 1866, the project was abandoned.

Although under no legal obligation to do so, because the company promoting the overland line was separate, Western Union, realizing a moral obligation to those whose stock had become worthless, shouldered the loss of $3,000,000. Out of the expedition grew many important things, such as the purchase of Alaska from Russia, the mapping and exploration of thousands of miles of unknown Arctic wilderness, and the development of telegraph business linking the Orient with Europe and America by the Siberian line, which the Russians completed to the Pacific Ocean. The purchase of Alaska was the outcome of a conversation between President Hiram Sibley, of Western Union, and Premier Gotchakoff, of Russia. After their talk, in which a willingness to sell was expressed by the Premier, Mr. Sibley asked President Pierce, of the United States, to act speedily in making the purchase.

Gradually, through purchase, lease, or stock ownership of 538 telegraph and cable corporations and properties, and by the construction of new lines, Western Union became the national telegraph system, embracing practically every community in the United States; and now, through its 19,500 offices, it handles over 80 per cent of the telegraph business of the country. (The balance is handled by Postal Telegraph, Inc.)

The greatest period of development in the company's history has been in the last three decades. Additions and betterments to the plant aggregating $201,565,000 in that period have increased the book value 150 per cent. The company's gross annual revenues and income from its land-line and cable systems increased from $33,889,000 in 1910 to $101,278,000 in 1940, or 199 per cent.

Technical development. Thirty years ago, iron wire was in general use; today 76 per cent of all land-line wire used is of copper.

Mechanical development of the telegraph kept pace with the growth of business, miles of wire, and number of offices. In 1855, David E. Hughes of Kentucky produced a greatly improved House printer, with

a pianolike keyboard and many mechanical improvements. The development and general use of automatic telegraphy did not materialize, however, until later years, when it was necessary to handle a large volume of traffic over a relatively small number of wires.

In the 1850's, the duplex telegraph, which permitted sending messages in both directions at the same time over the same wire, was invented and developed by Gintl, Frischen, Siemens, and Stark. J. B. Stearns, of Boston, is credited with introducing and improving duplex telegraphy in America, thus doubling the capacity of existing telegraph circuits.

Thomas A. Edison's contribution. Thomas A. Edison, one of the greatest telegraph inventors, was largely responsible for the quadruplex, the next step in telegraphy. He applied for no less than 1,000 telegraph patents between 1860 and 1910. Edison began this work as a Western Union operator, and later had the financial backing and used the facilities of Western Union while developing the quadruplex. His purpose was accomplished by combining a modified single-current system with a double-current duplex, and the invention thus saved the telegraph company millions of dollars in construction costs.

Edison contributed many other important telegraph inventions, one of which was his two-wire universal stock ticker, an improvement of the first successful ticker, invented by E. A. Calahan. Of all the tickers invented in the early years of the business, Edison's alone has come down to us practically unchanged, and some thousands of these instruments are still being used in some of the minor ticker systems operated by Western Union.

After inventing his first major ticker improvement—a device for bringing tickers into unison from the central office—Edison was asked by General Marshall Lefferts, then head of the Commercial News Department of Western Union, how much he would take for his ticker improvements to date. Edison started to answer $3,000 but hadn't the nerve to name such a large sum. General Lefferts asked if $40,000 would be satisfactory, and Edison nearly fainted. That money gave Edison his real start; he rented a shop at Newark and began producing tickers and other instruments.

Automatic telegraphy. The wire mileage of the company increased from 153,000 miles in 1875 to 1,913,000 in 1939, but the increase in the capacity of the system was far greater, owing to improvements in the art of telegraphing. The multiplex telegraph system, in general use on trunk lines between cities, permits the transmission, at high speed, of as many as eight messages simultaneously over one wire, four in each direction.

Such messages are written by operators on keyboards similar to those of typewriters. As the keys of the instruments are struck, holes are perforated in a narrow paper tape. Letters of the alphabet and other characters are represented by combinations of five holes in the tape The tapes pass into transmitters, and the impulses, caused by electrical contacts controlled by the holes in the tapes, flash out over the wire. Upon reaching the other end of the wire, the impulses are translated

back into characters and printed on tapes, which the operators gum to message blanks.

Four sending and four receiving machines may be attached to each end of a wire connecting two cities, and from two to eight messages, depending upon traffic requirements, passed over the one wire simultaneously. By means of an automatic control device, the sending and receiving operators can instantly communicate with each other should communication become necessary during the transmission of a message.

The teleprinter, which has been placed in general use, is suited to short circuits where traffic is light. It is a compact machine, a trifle larger than an ordinary typewriter, and weighs less than 70 pounds. Like the Multiplex, it is operated from a keyboard similar to that of a typewriter keyboard

Installation of thousands of teleprinters in the offices of Western Union customers has practically added as many new, direct-wire offices to the 19,500 telegraph offices of the company. The printer in the customer's office is connected directly with a similar machine in the local telegraph operating rooms, and messages are sent back and forth, making deliveries between the two points practically instantaneous. Also, there are more than 15,000 Western Union agencies at which telegrams may be sent. Moreover, every coin-box, office, or home telephone is a station from which telegrams may be filed.

A development by Western Union engineers which is producing important changes in the telegraph system is the automatic telegraph, which utilizes the facsimile process and provides a method so simple that the sender needs only to drop his telegram into the slot of an automatic telegraph cabinet. Electricity does the rest, wrapping the message around a cylinder and flashing it to the main telegraph office. Western Union engineers also have developed a method by which pictures of high quality are sent by cablephoto from London to New York.

Varioplex, another important development, enables Western Union to offer Telemeter Service, by which telegrams of big users are measured with a word meter for each patron employing this service. The charge is for the number of words a patron transmits monthly. Introduction of automatic relaying, automatic repeaters, teleprinter-multiplex repeaters, and carrier circuits also has made possible the adoption of new operating methods.

Now, approximately 94 per cent of the nation's telegraph business is handled by automatic methods, and the progress of the industry is in the direction of a greater degree of automatic, faster, and more accurate operation. In spite of this tendency, however, telegraph officials doubt if the Morse operation will ever be entirely abandoned, because of its greater flexibility under certain conditions, such as the reporting of sports and other events by reporter-operators. There are still a number of Morse operators in all large telegraph offices.

Leaders responsible for our telegraph system. Symbolic of the policies which developed the national telegraph system known as Western Union is the character of the men who have directed its progress.

Led by Hiram Sibley, Samuel L. and Henry R. Selden, and Ezra Cornell, whom we have noted, a group of Rochester, New York, residents organized the New York and Mississippi Valley Printing Company in 1851. These far-sighted leaders had visions of a great telegraph system at the very outset and pressed on in the face of financial loss and great difficulties, buying in other companies operating in the Midwest and extending their lines. The first board of directors included Henry S. Potter as president, Joseph Medberry as vice-president, Isaac R. Elwood as secretary and treasurer, Hiram Sibley, Judge Samuel L. Selden, Ezra Cornell, Don Alonzo Watson, Isaac Butts, Alvah Strong, Freeman Clarke, George H. Mumford, and J. M. Howard.

After consolidating with the Erie and Michigan Telegraph Company, which was operating under valuable grants of Morse patents held by Ezra Cornell, in 1856 these men further displayed their vision by selecting the name "Western Union." Hiram Sibley was elected president.

Mr. Sibley was one of the most forceful figures of his time. In his 9 years in office, he pushed Western Union rapidly toward national size, *building the first transcontinental telegraph and attempting to construct* the overland line to Europe by way of Alaska and Siberia. An illustration of Mr. Sibley's forcefulness was his declaration, when his board expressed reluctance to build the line to the Pacific: "Gentlemen, if you won't join hands with me in this thing, I'll go it alone."

The caution of the board members prevailed to some extent, for separate companies were formed by Western Union to handle this construction. After the line was built, the construction companies were merged with the parent company.

No summary of telegraph development in that period would be complete without mention of Edward Creighton, who surveyed and built the eastern end, and James Gamble, who was in charge of construction of the western end of the transcontinental line.

One of the greatest of business diplomats was Jeptha H. Wade, who succeeded Mr. Sibley as president in 1865. Mr. Wade had been an active pioneer builder of telegraph lines in the Midwest, and he came to the company in 1854, when his Erie and Michigan Telegraph Company was consolidated with it. His strategy was also seen in the federation of the Pacific Coast lines and their merger with Western Union.

In 1866, the company moved its headquarters from Rochester to 145 Broadway, New York City. Mr. Wade retired because of poor health, after serving 2 years, and selected as his successor William Orton, former United States Commissioner of Internal Revenue and president of the United States Telegraph Company. Mr. Wade had just completed negotiations for consolidation with the latter company and with the American Telegraph Company.

Rapid growth of business marked Mr. Orton's administration. In 1872, the number of telegrams handled daily in the New York operating room was 3,500, a large figure then, but small now as compared with more than a quarter of a million handled daily through the New York central operating rooms. Mr. Orton saw the need of larger headquarters,

and erected at 195 Broadway what was hailed as one of the "most magnificent and colossal" structures of the day. It was occupied in 1875.

A fire destroyed the upper floors of the building in 1890, and it was rebuilt and reoccupied in 1892. Dr. Norvin Green, a physician who organized the Southwestern Telegraph Company, became vice-president of Western Union during the mergers of 1866 and president on the death of Mr. Orton in 1878. When Dr. Green died in 1893, General Thomas T. Eckert, chief of the War Department Telegraph Staff during the Civil War, who performed confidential missions for Abraham Lincoln and later was Assistant Secretary of War, was promoted to the presidency of the company Another Civil War telegraph figure, Colonel Robert C. Clowry, succeeded Mr. Eckert in 1902 and held office until November 23, 1910.

The years 1909 and 1910 marked the real inauguration of modern telegraphy as a commercial business being pushed through sales and public-relations efforts. In 1909, the American Telephone and Telegraph Company acquired control of Western Union by purchasing the stock of the Gould estate, and Theodore N. Vail, president of the American Telephone and Telegraph Company, became also president of the Western Union on November 23, 1910. Newcomb Carlton, formerly an American telephone man and then managing director in London of the British Westinghouse Company, was brought over and made vice-president.

The Western Union service and plant at that time was more or less run down, and Mr. Carlton was given the job of carrying out a campaign of progress and reform. Dingy telegraph offices were replaced with polished oak and shining plate glass; courtesy and prompt attention were stimulated. When it was learned that the telephone subscriber could take down the receiver and ask for Western Union, send a telegram, and have it charged to his telephone account, the public realized that a revolution had taken place in telegraph service.

Mr. Vail instituted a campaign of public education to which the people responded. Business of the Western Union showed an increase of $5,000,000 in the first year. In 3 years, the gross revenue increased 45 per cent and wages to operators were increased 55 per cent. To allow the public to utilize the quiet hours when operators had little to do and lines were nearly idle, the night letter was created in 1910 and the day letter in 1911, followed by the cable letter and week-end cable, as deferred cable services at low rates.

The rearrangement program had hardly run 3 years before the Department of Justice questioned whether the two companies were not violating the Sherman Anti-Trust Act. The American Telephone and Telegraph Company then sold its holdings of Western Union stock and Mr. Vail retired from the latter company so that the control and management would be entirely independent. On April 15, 1914, he handed over to his successor as president, Mr. Carlton, the task of carrying on the program of progress which had been instituted.

When the Government took control of all communications companies during the First World War, in order to safeguard and control their

operations, Newcomb Carlton was placed in charge of the operation of all cables, and a board of officials was named to operate the telephone and telegraph companies. The financial structures and organizations of the companies were otherwise not affected After operating the communications lines at a substantial loss from November 2, 1918, to July 31, 1919, the Government restored the lines to their owners.

One great physical step forward came with the completion, in 1930, of a great national headquarters building, the largest telegraph building in the world, at 60 Hudson Street, New York City. "Moving day" required 6 months, but finally all headquarters departments, the Metropolitan and Eastern Division headquarters offices, and the New York operating rooms were all housed under one roof. More than 6,000 employees were thus grouped in the building.

In other cities throughout the nation the company has erected fine buildings which give outward evidence of the size and importance of the industry. These great buildings and the many other offices and miles of line of the great telegraph system stand as monuments to the American passion for efficiency and speed in the transaction of their personal and business affairs.

R. B. White, then president of the Central Railroad of New Jersey, became president of Western Union on June 1, 1933, and Mr. Carlton became chairman of the board. Among the more outstanding accomplishments of Mr. White's administration are: a new era of technical progress and developments, marked by the automatic telegraph, cablephoto, carrier system, and varioplex (see page 750); a broadened business use of telegraph services through the establishment of the new overnight telegram, and telemeter, tourate, and serial services; larger use of telegrams for social purposes through low-rate greeting services for holidays and special occasions; a progressive public-relations program to keep the public, stockholders, and employees informed; and other developments too numerous to list here Mr White resigned on June 1, 1941, to accept the presidency of the Baltimore and Ohio Railroad. Mr. A. N Williams, president of the Lehigh Valley Railroad, was elected to the presidency of Western Union on June 17, 1941, succeeding Mr. White.

Postal Telegraph, Inc. Up to this point, we have considered primarily the Western Union There is one other large telegraph company in the United States, Postal Telegraph, Incorporated.

The following excerpts from a statement[1] made during 1930 by the late Clarence H. Mackay, then chairman of the board of Postal Telegraph, describe the Postal system and give its history:

> The Commercial Cable Co., which was founded by my father in 1884, owns and operates six trans-Atlantic cables between New York and England. All of these cables touch at either Nova Scotia or Newfoundland and Ireland, en route to England. Two of them also touch at the Azores before reaching Ireland. There are also two cables

[1] Testimony before the Committee on Interstate Commerce, United States Senate, pp. 1,665-1,667 (United States Printing Office, 1930).

between Ireland and France. Hence we have six routes to Europe, five of which are permanently automatically joined through to London or Liverpool, and one with Paris.

In addition to this, we lease from the Western Union two out of five channels which they have in their cables between New York and the Azores, these two channels being used for connection with similar channels in a cable belonging to the German Company between the Azores and Germany.

The Commercial Pacific Cable Company owns and operates a cable starting at San Francisco and touching Honolulu, Midway Islands, Guam, Manila, and Shanghai, China, with a spur line from the island of Guam running up to the island of Bonin, where it connects with a Japanese Government cable to Tokio.

The Postal Telegraph system, which since 1886 has been in the domestic telegraph business in the United States.

The Mackay Radio & Telegraph Co. . . . .

The situation in or about the year 1882 in the trans-Atlantic cable field was that there were four trans-Atlantic cable systems, namely, the Anglo-American Telegraph Company and the Direct United States Cable Co., both British companies; The French Cable Co., a French company; and the Western Union Telegraph Co., an American company. These companies had complete control of the cable field.

These companies had an arrangement providing for the maintenance of a 50-cent word rate across the Atlantic. There was considerable agitation against the companies on account of the high rate maintained and also the poor class of service.

The original rate established on the opening of the first trans-Atlantic cable was $100 for 20 words. By successive reductions the rate was brought down to 50 cents a word in 1880.

John W. Mackay, my father, and James Gordon Bennett, who was the owner of the New York Herald and who was probably the largest cable user of his time, joined hands to organize an American cable company which would give cable service at lower rates. In September, 1883, a co-partnership was formed between John W Mackay and James Gordon Bennett, which later, on December 12, 1883, resulted in the incorporation of the Commercial Cable Co., which was known as the Mackay-Bennett system.

The Commercial Cable Co. immediately ordered the manufacture of two trans-Atlantic cables. These two cables were completed and opened for service in 1884.

On completion of these cables the cable rate was reduced from 50 cents to 40 cents a word.

This soon resulted in reprisal on the part of the other cable companies, which, in an effort to force the Commercial Cable Co. into bankruptcy, reduced the cable rate from 40 cents to 12 cents a word. The Commercial Cable Co. thereupon reduced its rate from 40 cents to 25 cents a word and appealed to the public for support on the ground that the 12 cent rate was a confiscatory rate and would not be maintained by the other cable companies if they were successful in bringing the Commercial Cable Co. to its knees.

The Commercial Cable Co received strong public support but on September 15, 1887, it also reduced the rate to 12 cents a word. This rate, however, being wholly unprofitable for all parties concerned, the rate was established at 25 cents a word in July, 1888, by all companies, after one of the most bitter fights on record.

In the meantime, John W. Mackay decided to enter the landline telegraph field in competition with the Western Union in the United States. It was, however, a colossal task to attempt to build up a com-

> prehensive landline system throughout the United States because, as far back as 1881, the Western Union Telegraph Co., under the leadership of Jay Gould, had acquired control of all the Commercial telegraph lines in the United States and, through his financial power, had secured contracts for the Western Union with practically all of the important railroads. . . .
>
> Nevertheless, the demand for competition and the growing requirements of the public, the disposition to exploit new systems of transmission, together with purely speculative enterprises, resulted in building up between the years 1881, 1884, and 1885 a more extensive, diverse, and damaging competition than had ever before existed. The Mutual Union, the American Rapid, the Bankers and Merchants, the Baltimore and Ohio, the Southern, the Board of Trade, the Pacific Mutual, and the original Postal were among the most extensive and important of the corporations that were formed, and all were competing with each other as well as with the Western Union Co in the most wasteful manner.
>
> In this almost chaotic condition of affairs of the telegraph, John W. Mackay came into the control of the property, bearing the Postal name, which had gone into the hands of a receiver, and which only owned a few hundred miles of scattering telegraph lines, practically all land.
>
> The Postal Co. immediately began to build telegraph lines and also purchase various lines (or companies) which had become insolvent. It began business with lines between New York and Chicago, New York and Washington, Buffalo and Pittsburgh, Chicago and St. Louis, and various other less important lines.
>
> With the above lines as a nucleus the company went ahead and constructed various lines and made various connecting-line contracts and purchased the property and franchises of the Michigan Postal Telegraph Co, and a line between Pittsburgh, Cincinnati, and Indianapolis and acquired, through purchase of stock, the line of the Pacific Mutual Telegraph Co, the Board of Trade Telegraph Co, the Pacific Telegraph Co, and various other companies besides building a great many lines itself in different parts of the country. . . .
>
> In the meantime, the Postal Telegraph system was being rapidly built up throughout the United States and it was deemed advisable for the Commercial Cable Co. to purchase this property and to secure its control for all time for the protection of the interest of the Commercial Cable Co and the maintenance of its position in the Atlantic Cable service. Accordingly, on January 1st, 1897, the Commercial Cable Co. acquired the stock and property of the various Postal Telegraph Cos. throughout the United States by acquiring the $15,000,000 capital stock of the Postal Telegraph Cable Co (New York). . . .

On May 15, 1928, the Postal and Commercial systems merged with the International Telephone and Telegraph Corporation, which operates telephone companies in a number of foreign countries.

On January 30, 1940, *Postal Telegraph, Incorporated*, was established as a company completely independent of the International Telephone and Telegraph, consummating a reorganization of Postal under proceedings started June 14, 1935, under section 77B of the Bankruptcy Act. At the same time, three companies were formed, the All America Corporation and the Commercial Mackay Corporation, to take over the international telegraph system of the International Telephone and Telegraph, and the American Cable and Radio Corporation to hold the equity of the first two. Frank W. Phelan was elected president of all three, and Edwin F. Chinlund became the president of the new Postal Telegraph, Incorporated

Size of the industry. The size of the telegraph industry was indicated by a report of the Federal Communications Commission entitled, *Selected Financial and Operating Data from Annual Reports of Telegraph, Cable and Radiotelegraph Carriers, year ended December 31, 1938.* This report shows a total investment in plant and equipment of $537,000,000, and an aggregate capital stock of the industry of $165,000,000. The telegraph, cable, and radio operating revenues of these companies is given as $133,000,000. The total wire mileage for the industry is reported as 2,400,000 miles and the number of persons employed as 65,000. The number of telegrams sent in the United States in 1912, which was 106,533,000, has more than doubled since that time.

Important legislation affecting the industry. The Post Roads Act of 1866 gave to any telegraph company the right to construct, maintain, and operate telegraph lines through any portion of the public domain of the United States and over and along any of the country's military or post roads. It also gave the postmaster general the power to fix the rates which the telegraph companies would be permitted to charge for United States Government messages.

In 1910, the jurisdiction of the Interstate Commerce Commission was widened to include the telegraph, telephone, and other companies, and the companies in question were required to make regular reports to the Federal body concerning their operations.

The Kellogg Act, to prevent the unauthorized landing of submarine cables in the United States, was enacted by Congress in 1921. This bill gave the United States Government authority to deny the landing of new cables connecting this country with foreign lands.

The Webb-Pomerene Act of 1918 permits combinations of persons in the United States for the purpose of selling American goods abroad. However, the Radio Act of 1927 excludes the radio from the list, expressly prohibiting the purchase, lease, construction, or control of any wire telegraph or telephone line or system by a radio company or vice versa, the purpose of which would be to lessen or restrain competition in the business of transmitting messages. This act reads in part:

> All the laws of the United States relating to unlawful restraints and monopolies and to combinations, contracts, or agreements in restraint of trade are hereby declared to be applicable . . . to interstate or foreign radio communications.

The Radio Act also created the Federal Radio Commission, with broad powers as regards the issuance of licenses and the establishment and regulation of radio facilities.

The Communications Act of 1934 established the Federal Communications Commission as a Governmental regulatory body with jurisdiction over all methods of rapid communications and with the powers and duties over communications formerly in the hands of the Interstate Commerce Commission, the Federal Radio Commission, the postmaster general, and others. The provisions of the act generally were taken from the Interstate Commerce Act, the Radio Act, and other laws previously relating to communications.

Economic Significance of the Industry to Our Present Industrial Development

The vital relationship between the telegram and business. The great majority of telegrams and cablegrams are sent for business purposes. Driven by the lash of competition, business must perforce move faster and faster, or else fall behind in the race. Negotiations must be conducted rapidly, decisions arrived at quickly, and transactions across the continent closed on the moment Time is the most valuable commodity in business life, and telegrams and cablegrams are the greatest conservers of time in business transactions. The telegraph is, in fact, the nerve system of the business life of the nation.

No large and progressive business in the nation today fails to consider the use of either telegrams or cablegrams, or both, as one of its chief assets. The organization of large companies often includes a telegraph bureau, while smaller firms work in close coöperation with the nearest telegraph office. The very structure of business in America is built upon the communications offered by the mails, the telephone, and the telegraph—and not least important of these is the telegraph.

The telegraph has exerted a strong influence in the development of American industries. The effects may be seen in our business organizations, in decentralized management and production, in the establishment of warehouse and factory branches, in telegraphic direction of sales forces, in low inventories of stock replenished quickly by telegraphic orders, and in organization setups dependent for their workability upon fast interchange of orders and reports. A familiar illustration of this trend is the establishment of executive headquarters of companies in large cities, while factories, branches, sales agencies, and retail outlets may be scattered over the entire country. Consider the development of railroad transportation, with telegraph lines along the rights of way, or the air-transport companies, or the bus and motor-freight companies, requiring coördination of activities at widely separated points. On every hand there is evidence of the vital part the telegraph plays in business.

Recently an American firm sold a large order of road-building apparatus to a company in equatorial Africa. How? Four Western Union cablegrams were sent to follow up their printed matter. At the telegraph company headquarters are literally thousands of letters from patrons who were so impressed with the efficacy of telegrams and cablegrams in various uses that they expressed appreciation in writing, many indicating amazement at results.

Telegrams denote urgency. They always get there, are opened first, and are read. They are the red flag of correspondence and demand attention. For that reason, firms having propositions to make or points they wish to emphasize have found that it pays to telegraph. If a company president wishes to impress his sales force with a special message, he wires it to the field. A hatter wires prospective customers of a special sale. An automobile dealer speeds sales by telegraphing prospects that he has a new model, urging them to see it. In such cases, the

telegraph company is given one message and a list of names and addresses. Such large distributions are known as "books" of messages, costing, for local delivery, 20 cents for each 10-word telegram or for the first 50 words of an overnight telegram. (There are quantity discounts ranging from 10 to 50 per cent on local overnight telegrams of the same text.) And so it goes in every active line of business.

Companies take pride in the variety of their uses of the telegraph, for those uses are proof of the efficiency and moderness of their methods. They check the 31 major uses of telegrams, which have become well-known in the commercial world. The list follows:

1. Acknowledging first orders.
2. Telegraphing for credit information.
3. Expediting shipments.
4. Acknowledging complaints.
5. Price and style changes.
6. Announcing new enterprises.
7. Aids in meeting competition.
8. Paving the way for salesmen.
9. Invitation to buyers.
10. Reviving inactive accounts by telegraph.
11. Use of telegraph between salesmen's calls.
12. Encouraging purchase of additional items.
13. Use of overprinted blanks.
14. Supplementing advertising by telegraph.
15. Encouraging salesmen.
16. Instructions to branches and salesmen.
17. Stimulating sales campaigns.
18. Special sales.
19. Daily sales reports.
20. Quoting prices by telegraph.
21. Salesmen's orders by telegraph.
22. Answering inquiries.
23. Tracing orders or shipments.
24. Telegraphing shipping dates of orders.
25. Daily production reports.
26. Requesting replies to unanswered letters.
27. Accepting offers.
28. Requesting prices.
29. Replenishing stocks.
30. Money orders to salesmen.
31. Collection of accounts.

There are so many ways in which telegrams and cablegrams are used by enterprising business concerns that a chapter could be devoted to this subject alone.

Commercial development of telegraph business. The fact that the telegraph has become such an indispensable part of the business and social life of America is not a matter of chance. It is the result of many years of promotional work on the part of the telegraph companies. The telegraph, at its inception, was regarded by administrative officials and the public as an instrumentality for bridging distance in emergencies, and this concept lasted for a surprising length of time.

While a small bid for nonemergency use was early made by offering

an overnight service known as "night messages" at reduced rates, this service was used only to a very limited extent, and it was not until the advent of the night letter in 1910 and the day letter in 1911 that the telegraph began to take its proper place as an instrument of efficiency in the conduct of modern business.

From the standpoint of the telegraph companies, too many businessmen are still prone to rely on the physical transportation of their nonurgent communications; nevertheless, no inconsiderable part of the present large volume of telegraphic communications originates with patrons who recognize the peculiar attention-compelling properties of a telegram, the importance of short cuts, and the reduction of the time element in their correspondence.

The "magnificent distances" which separate places of commercial and social importance in the United States and which are not encountered in any other country of equal development undoubtedly represent another factor in the phenomenal growth of this traffic, but the outstanding element is the high standard of service that has been established and the indefatigable manner in which the private companies conducting the business have kept the utility of the telegraph before the public.

In all other countries, the domestic telegraphs are administered by the government, and the officials in charge take the business offered and are satisfied if the service is such that there is no general complaint or criticism. In this country, the present-day telegraph managers do not wait for the public to sense its need for quick communications but, by every method their ingenuity can devise, urge the advantages of a liberal use of the telegraph in the efficient conduct of business. They strive continually to adapt the service to the needs of particular industries or businesses, and various classifications of service have been evolved, with prices more or less suited to every purse.

Probably the best illustration of the effectiveness of these methods in the stimulation of traffic is found in the enormous business done during the Christmas holidays. Originally a day of few messages, because of the general suspension of business, Christmas has become the peak day of the year. The greetings are delivered on special blanks of a decorative character. Similar blanks suited to the occasion are used on all other special days throughout the year. Abroad, in the few countries that have a so-called "de luxe" service corresponding to our special services, a substantial extra sum is charged. On the contrary, in America, special rates, as low as 25 cents, are offered for greeting telegrams. These special days, which include Easter, Thanksgiving, Mother's Day, and others, are occasions for sending millions of greeting telegrams each year.

For the purpose of enabling the public to send telegrams with the same clarity of meaning and as freely, easily, and fluently as any other form of communication, punctuation marks are included free when they are used in the text of telegrams to points in the United States. Also telegrams written in paragraphs are delivered in paragraphs, without any

extra charge. Figures are counted and charged for as one word for every five figures or fraction of five figures.

As a result of the modern intensive commercial development of telegraph business in the United States and the response of the American public, the industry in this country has grown on a scale out of all comparison with that of any other country during the past three decades. At the beginning of that period, 90 per cent of the traffic was handled by manual Morse operation. At the present time, 94 per cent is handled by automatic apparatus. Through the installation of electrical repeaters, the relaying of messages has been greatly reduced, and New York and all other principal cities now exchange messages directly with each other.

Owing to these changes and to improvements in operating practices, the average delay of about 40 minutes between New York and Chicago in the earlier period has been reduced to slightly above 3 minutes, while many messages are handled between these and other large cities within 1 minute. Since 1914, more than 300,000,000 manual handlings annually have been eliminated by the establishment of direct circuits.

One of the greatest improvements has been in the continuity or certainty of service. The maintenance and arrangement of the major telegraph system is such that an interruption of service to or from an important point rarely occurs. Western Union's line-gang forces, the shock troops of man's battle to maintain uninterrupted communications in spite of all emergencies, number more than 1,000 men, not counting hundreds of section linemen who handle minor repair work. When floods sweep away homes, railroad tracks, and telegraph lines, when blizzards break ice-laden wires, when gales, hurricanes, and tornadoes snap telegraph poles and scatter wreckage, these men, in 100-line gangs, move to the front in their special trains, or homes on wheels, equipped to string up emergency lines and reëstablish contact with the outside world, to facilitate rescue and the transmission of news. They then rebuild the telegraph lines, restoring communication while everything around them is still in ruins.

Despite the cost of these improvements, there has been no increase in telegraph rates beyond a 20 per cent increase ordered by the postmaster general in 1919 during Government wartime operation. Transoceanic cable rates are now so low that a cablegram from New York to London costs 20 cents a word, and a cable night letter of 25 words may be sent for $1.67.

Comparison of British and United States rates. In Great Britain, where the government operates the telegraph at an annual deficit of several million dollars, the cost of service is comparatively high considering the small area served, which is less than half that of the State of Texas. A message can travel a maximum distance of only about 400 miles in Great Britain, but whether it travels 400 miles or only 1 mile, the charge is 24 cents for 12 words, including a full count of words for the addressee's name, the address, and the signature, which of themselves usually require about 12 words and are handled free in the United States.

A special charge is made for messages delivered on Sunday, Good Friday, and Christmas, and for all messages delivered beyond a certain limited distance from the nearest office. In the United States, no extra charge is made for delivery at any time at any distance within city limits.

Full-rate telegrams between New York and San Francisco cost $1.20 for ten words, with the address and signature free. A message traveling a similar distance by land line from London to, say, Bagdad costs 41 cents a word, with all words in the address and the signature counted. The number of telegrams booked in Great Britain has ranged from 47,400,000 in 1926–1927, and 56,479,000 in 1929–1930, to about 50,000,000 in 1936–1937, as compared with the increase from about 100,000,000 to more than 200,000,000 in the United States in the same period of time. Because of the unsatisfactory state of the telegraph service in Great Britain, a committee of experts was sent to the United States in 1928 to study the American system. Germany and Japan, also suffering from the inefficiency of government operation, sent experts to study American telegraph practices.

The Telegraph System of Today

How telegrams are sent and received. The average person's knowledge of telegraphy ends at the counter of the telegraph office, or, if it goes farther, erroneously defines telegraphy in terms of dots and dashes from the old-type Morse key and sounder, such as are still seen in many small railroad-station offices.

The fact that a telegram can reach a distant city and be read by the addressee in a few minutes is made possible only by a highly efficient organization and the maintenance of a great system of offices and wire circuits connecting every city and town in the nation. The operating equipment is concentrated at certain points, which are known as "main offices." These offices, acting as clearing houses for the surrounding areas, receive all telegrams from their areas and transmit them to their destinations.

Often the telegram is handed to a messenger, who responds to the signal from one of the half-million telegraph company call boxes in the offices of business patrons. Where there is a teleprinter in the business office, the telegram is not handed to a messenger but is given to the teleprinter operator, who, by the simple act of typing it on a typewriterlike keyboard, transmits the telegram to the nearest telegraph main office. From the home or business office, the message can be telephoned to Western Union. The act of dialing a designated number or of saying no more than the words "Western Union" to the operator automatically connects the sender with an experienced operator in the main telegraph office, who records the telegram on a noiseless typewriter exactly as it is dictated. The superrobot which automatically receives and distributes the calls of patrons to the recording operators at New York City is one of the remarkable inventions of recent years

It is interesting to follow the course of a telegram filed at a branch

office or handed to a messenger. The receiving clerk time-stamps it with an automatic device, then notes if the message is marked for a definite service, counts the words, and collects the fee. The telegram is then dispatched to the main office by wire or in a conveyor shooting at high speed through a pneumatic tube under the city streets.

Upon arrival at the main office, the telegram is immediately carried by a moving belt to the distributing center in the operating room, where deft fingers place it on another belt which flashes it across the room to an operator "working" a wire to the city of destination. If the operating position connected with that city is on another floor, the message travels by tube or fast conveyor belt to that floor; or, in large operating rooms, if the telegram falls within certain classifications, it is taken quickly to the operator by one of the girls who skim here and there on roller skates.

Upon being handed to the operator, the message is transmitted with lightning speed by teleprinter, multiplex, or, occasionally, by Morse telegraphy, to be translated automatically into words on paper again at the office of destination. If the destination is a city, the message will arrive at the main office and from there be sent by teleprinter or pneumatic tube to the branch office, where it will be inserted in an envelope and delivered to the addressee.

Telegraph and cable services. With the types of telegraph and cable service in use for years, the public is more or less familiar—the full-rate telegram, day letter, overnight telegram, full-rate cablegram, deferred (half-rate) cablegram, cable night letter, urgent service, code cablegram, and code urgent.

Overnight telegrams, formerly called "night letters," represent an overnight service for which the maximum charge for the first 25 words is 50 cents, even for the greatest distances in the United States. The rates for additional groups of 5 words decrease progressively as the length of the message increases. Quantity discounts are allowed for local overnight telegrams of identical text sent to a number of addressees in the same city. This service makes it possible for lengthy correspondence to be sent by telegraph at low cost.

Tourate telegrams are used by travelers to let the people back home know of their progress of their trips. They can be sent to any Western Union point in the United States at a cost of only 35 cents for the first 15 words.

For the convenience of patrons who have occasion to carry on intermittent communication with any one addressee during the course of a day, however, Western Union inaugurated the Serial Service Serials may be filed in sections during the day for transmission. The minimum charge per day is for 50 words, and individual sections filed are rated at a minimum of 15 words.

Timed wire service. Timed wire service is available to all who have automatic telegraph printers. It is a service by which the facilities of the telegraph company are placed at the customer's disposal on a time basis.

The charge is based on the time consumed by the sender in transmit-

ting the message to the telegraph company's operating room and on the distance to the point of destination. The minimum charge is for a period of 3 minutes and is twice the amount charged for a 10-word full-rate telegram between the same points. The charge for each additional minute or fraction of a minute in excess of 3 minutes is one third of the charge for the initial 3-minute period.

Timed wire service provides for the use of telegraph facilities for a period long enough to telegraph at length. It carries the full force of the dictator's expressions. His thoughts can be elaborated and the sense clarified. He is freed from the feeling that he must keep his message down to 10 or 50 words.

This service is most economical; approximately 100 words can be dispatched for the price of two 10-word telegrams.

Other important services. Besides the handling of telegrams and cablegrams, Western Union provides many other important services, a number of which are exclusive with the company. The international radio and ship-to-shore messages accepted and delivered by Western Union, through arrangements with R.C.A. Communications, Incorporated, and the Radiomarine Corporation, will be discussed in a separate chapter.

Commercial news department. Transactions in stocks, bonds, and commodities estimated at more than $90,000,000,000 were recorded and distributed in 1930 over the 28 separate ticker systems operated by the Western Union. This sum, it is estimated, is approximately equal to the total sum of money spent last year by every man, woman, and child in the nation.

Most of these 28 ticker systems report transactions on the principal stock and commodity exchanges on thousands of tickers, located in all cities and numerous smaller places. Trading in stocks, bonds, and commodities reported on the tickers totals many billions of dollars each year.

Aside from the New York Stock and Curb exchanges, with their stock and bond ticker systems, others of the 28 ticker systems are: the Baltimore Stock Exchange, the Chicago Board of Trade (handling grain, provisions, securities, cotton, and soybeans), the Chicago Mercantile Exchange (handling butter, eggs, and hides), the Chicago Stock Exchange, the Detroit Stock Exchange, the Duluth Board of Trade (handling grain), the Kansas City Board of Trade (handling grain), the Los Angeles Stock Exchange, the Marine News of the Port of New York, the Minneapolis Chamber of Commerce (handling grain), the New Orleans Cotton Exchange, the New York Cotton Exchange (handling cotton and wool), the New York Cocoa Exchange, the New York Coffee-Sugar Exchange, the Commodity Exchange of New York (handling silk, rubber, hides, copper, lead, tin, and zinc), the New York Produce Exchange (handling cottonseed oil, tallow, and pepper), the Philadelphia Stock Exchange, the San Francisco Stock Exchange, the Toronto Stock Exchange, the Winnipeg Grain Exchange, and various combinations of service of the above exchanges, as well as baseball-sports tickers carrying reports of practically

all organized baseball leagues and of football, hockey, basketball, and other sports.

The above list does not include a score of commodity and exchange reports furnished by Western Union to subscribers by means other than tickers. These reports include, in addition to stocks and commodities, information on such commodities as flax, rice, poultry, potatoes, livestock, cabbage, celery, cheese, naval stores, and citrus fruits, as well as regular reports sent to and from exchanges and markets in all parts of the world

The Commercial News Department, in charge of all of these ticker and commercial reporting systems, transmits from the Western Union headquarters, at 60 Hudson Street, New York City, the majority of the quotations of the nation's business, yet the scene is one of perfect order and precision.

Time service. Throughout the day, Americans are timed by the Western Union network, which has provided the nation with standard time for over 50 years, whether the time is obtained by radio or telephone or at office, factory, store, theater, or school.

"Click, click! Click, click!" daily chorus special telegraph instruments in Western Union offices in towns and cities throughout the nation for 3 minutes at noon, in perfect measure with the tick of the secondhands of the precision clocks maintained by the United States Naval Observatory at Washington, D. C. Finally, the instruments are silent for 10 seconds before noon, then click the instant of 12 o'clock, Eastern Standard Time.

In over 2,000 places, the local master clocks are simultaneously checked and finely regulated with these clicks or time beats. The master clocks, in turn, automatically send hourly synchronizing signals to each Western Union self-winding clock in local subscribers' premises, thereby assuring time accuracy 24 hours per day. Regardless of any slight drift from current time, either fast or slow, all subscribers' clocks receive the correcting signal each hour. These master clocks in many large cities are equipped with contacts in order constantly to transmit second beats over special wires to jewelers and watch repairers for use in regulating the rate of watches. Thousands of these clocks provide railroads, subways, and other transportation systems with operating time. It is a subject for conjecture, however, whether the time of more millions is regulated by these clocks or by time announcements from several hundred radio stations that announce from the Western Union clocks in their studios.

How is this time obtained? The earth itself is the fundamental clock, rotating once a day on its axis, but astronomers say the rotation is slowing down, owing to friction of the tides, and that the days are steadily becoming longer Furthermore, the earth is running irregularly, as indicated by shifts in our views of the moon. This is said to be due to expansions or contractions of the whole earth or to shifts in the inner strata.

Because of these irregularities of the earth, earth time is not correct,

and the error is calculated by observations of the time when certain stars reach a point due north or south or when the moon passes before stars and permits comparison with the spot it should have occupied at a given time. These corrections are made on the United States Naval Observatory transmission clock prior to its sending the noon time beats, which the Western Union network distributes to the nation.

A vital role in this distribution of time in the New York metropolitan area is played by two great master clocks and other apparatus in a vault beneath the Western Union headquarters building in New York City. The two clocks are mounted on massive concrete pillars, but the four legs of each "float" on concealed springs, which absorb any tremors of the earth. Each of the pendulums contains 30 pounds of mercury.

The temperature of the vault is automatically controlled. It is rarely necessary to open the vault doors and disturb the air within or to open the clocks, because the clocks are kept in perfect synchronization with the time of the United States Naval Observatory by a remote-control system. On an upper floor of the building, the beat of the seconds by these clocks and by those in the Naval Observatory at Washington are recorded, side by side, on a moving tape by a chronometer. The slightest deviation from the Naval Observatory time is immediately corrected. The synchronizing impulse may go to fire or police headquarters, to the sidewalk or store-window clock, or to the factory, or it may sound the gongs at the local school; but practically everywhere we go and whatever we do, we may be sure of finding at our elbow Western Union time, identical to the instant with that at every other point in the country.

An important feature is a device which automatically flashes a signal each hour simultaneously over a large number of circuits controlling thousands of clocks. Another feature is a machine which automatically tests each of these circuits and prints on a tape the identifying number of any circuit requiring attention.

Money orders and gift orders. To meet the insistent demand of an occasional patron to have money paid quickly at a distant point, the Western Union, in October, 1870, inaugurated a service of transferring money by telegraph.

The cost was high, and orders were confined to extreme emergencies. After 30 years, less than $4,000,000 was transferred each year in less than 100,000 orders. The record of the next 30 years portrays the sentiment of the public in availing themselves of this service to speed up business. With a reduction in rates, there was a gradual and almost uniform increase from year to year until the First World War, when millions of Americans were concentrated in camps and sent overseas. Then fathers and mothers, filled with anxiety for the comfort of their absent ones and knowing that money in hand was always welcome, began to make a rapidly increasing use of Western Union telegraphic money orders in every city, town, and village. There was a deluge of these money orders, and the greatest credit is due Army officers for their

coöperation, both at home and abroad, in finding those to whom the orders were addressed, scattered over two continents.

After that came the postwar expansion and deflation, but the public had become familiar with the service and it continued to grow. During 1929, it was about double the great war business, and $275,000,000 were transferred in 4,500,000 orders. This volume comprised about 93 per cent of the nation's telegraphic money orders. During the subsequent decade, the volume of telegraphic orders was affected by the trend of business conditions, but successive increases over several years indicate that the current 1941 volume will be more than 93 per cent of the 1929 all-time high figures.

The gift order was offered to the public November 1, 1928, as an addition to the regular money-order service, although it had been offered in holiday seasons for 2 years prior to that time. It is actually a special check which will be accepted at any store when the recipient buys the gift he or she most desires. Because the average gift rarely fills a need of the recipient and often duplicates a gift already received, recipients everywhere are enthusiastic in their praise. The gift order merits its name, "the perfect gift." The gift order, together with an attractively decorated card bearing the name of the sender and a suitable telegram at no extra cost, is delivered in a special envelope in keeping with the spirit of the gift.

Western Union also offers a shopping service which enables patrons to have telegraph offices at any of 3,000 points complete the purchase and delivery of certain commodities. The articles most frequently telegraphed are candy, books, flowers, fruit, and cigars; theater, railroad, and steamship tickets; reservations for football and baseball games; and many other items that are sent every day for gift or business purposes.

American Express money orders and travelers' cheques. To meet public demand for a money order to be mailed or sent by methods other than the telegraph, the American Express Company and Western Union, in 1931, inaugurated such a service on a nation-wide scale. Western Union main and branch offices began the sale of the money orders, and American Express Company offices began accepting Western Union telegrams, cablegrams, and telegraphic money orders. Later, Western Union began the sale of American Express Travelers' Cheques.

Messenger-errand service. Realization by businessmen in recent years that fast special-delivery service is available anywhere at a moment's notice by an army of 15,000 Western Union messengers has resulted in a rapid growth of this type of business.

Retail stores in New York City alone use this messenger-errand service each year for the delivery of hundreds of thousands of articles, often after their regular deliveries have been sent out and patrons wish articles delivered in a hurry. Most of the Fifth Avenue stores use this service. Energetic sales managers have seized upon the idea as a business-getter and have advertised speedy deliveries, and other stores have adopted it for its novelty, economy, and good-will-building values.

Manufacturers and wholesalers have shown the greatest increase in

their demands for this type of service. By studying their delivery systems, they discovered they were maintaining large fleets of trucks and messengers that spent many idle hours on the average day and yet were inadequate on heavy days. Silk and dress manufacturers were among the largest users, one company even advertising delivery to any firm in the garment center within 20 minutes of receipt of an order.

Manufacturers desiring to distribute catalogues, samples, or introductory packages of products to persons or stores in cities and towns throughout the country have found that this service offers a great saving. These deliveries are often accompanied by sales telegrams. Cigar manufacturers, advertising agencies, dealers in blueprints and photostats, bond and financial houses, and florists are also among the large users.

At the request of the public, Western Union messengers pick up packages weighing less than 20 pounds for shipment by rail or air express through the Railway Express Agency. The messenger-service charge is paid by the Railway Express Agency

Messengers are also called upon for an endless variety of personal errands, ranging all the way from taking a child to the movies to feeding pigeons in the park.

Air reservations. For the convenience of the public, practically all air lines in the United States have made arrangements with the telegraph companies providing for free reservation service. All anyone wishing to travel by air has to do in order to obtain information regarding air routes and schedules and to reserve a seat is to telephone or visit the nearest telegraph office, and the service will be given without charge to the traveler. This arrangement, by which the air-transport companies have made their services readily available to the public, has aided the growth of air travel.

Teleregister The Teleregister Corporation, a subsidiary of Western Union engaged in supplying centrally operated quotation-board service to stockbrokers, is steadily extending its system to the principal cities of the nation. With Western Union's installation of high-speed stock tickers on its New York Stock Exchange quotation system, the old-fashioned boards, on which boys chalked up stock quotations, became hopelessly slow on days when the market was active The demand for the fast, automatic teleregister board increased correspondingly.

American District Telegraph Company. The American District Telegraph Company, another affiliate of Western Union, which provides fire, burglar, and other protection throughout the country, is not in the communications field and therefore will not be included in this study.

Internal Organization of a Telegraph Company

Western Union's organization is divided into six departments—plant, traffic, commercial, engineering, public relations and contracts, and accounting—each headed by a vice-president. The plant department constructs, reconstructs, and maintains the outside plant and installs equipment. The traffic department assigns the circuits to be used for the

transmission of messages and has charge of the actual operation in the operating rooms of the larger offices. The commercial department has charge of the sale of services, the management of the offices, and local accounting; and operates the branch offices, messenger service, and smaller offices in their entirety. The engineering department controls research and design. The accounting department has general supervision of accounting and audits.

The United States is divided into six major geographical divisions—Metropolitan, Eastern, Southern, Lake, Gulf, and Pacific. Each department, except the engineering and the public relations and contracts departments, has its own divisional organization. In each division, there is a divisional plant superintendent, a divisional traffic superintendent, a general manager in charge of the commercial department, and a divisional auditor, each reporting to the vice-president of his department in New York City. For commercial-department purposes, the divisions are subdivided into districts, usually including one city, or following state lines and headed by superintendents. The superintendents direct the work of all managers and other commercial employees in their territories.

The departmental vice-presidents are responsible for the functions of their departments in respect to the cables as well as the land lines, with the exception that the responsibility for repair and maintenance of cables by the fleet of Western Union cable-repair ships is supervised by the vice-president in charge of engineering. General supervision of cable administrative matters for the world is in the hands of the first vice-president.

On the European side, there is a general manager in London and another in Paris in charge of cable service in assigned areas. The organizations of these general managers correspond with those of the divisional general managers in the United States. The London organization is also responsible for Western Union business in the various offices in the other European countries. There are also European plant, traffic, and accounting forces similar to those in the United States, all coördinating their work.

Western Union Cable System

In 1882, Western Union entered the cable business by leasing from the American Telegraph and Cable Company two transatlantic cables which that company had laid between Penzance, England, and Canso, Nova Scotia, with land-wire connections between Canso and New York. The lease, extending for 50 years, would have expired in 1932, but Western Union purchased the cable company in 1930 and thus acquired the cables.

In 1911, Western Union leased from the Anglo-American Cable Company (British) its Atlantic system of five cables and subsequently laid three loaded or permalloy cables, one to England and two to the Azores, making ten in all, which, with cables to Cuba and one to Barbados,

connecting there to South America through the Western Telegraph Company, constitute the main arteries of the Western Union cable system. The company's cables to the Azores connect with those of the German Cable Company and the Italian Cable Company, thereby providing direct connections with Germany and Italy.

In 1926, the company acquired a controlling interest in the Mexican Telegraph Company, which owns and operates two submarine gulf cables between the United States and Mexico and several connecting land lines into Mexico City. For the care of all cables, the company has built two ocean-going cable ships, the *Lord Kelvin* and *Cyrus Field.*

Improvement in design of cables. From 1866, when the first successful transatlantic cable was laid, until 1924, no material change in the design of ocean cables had been made. In general, they differed only in size and weight. Western Union inaugurated a new era in cable history by the use of a revolutionary and brilliant development in the laboratories of the American Telephone and Telegraph Company. In 1924, a cable of this new type was laid between New York and Horta, in the Azores, in which the single copper conductor was wound with a wafer-thin ribbon of metal known as "permalloy," which, at a slightly higher cost, greatly increased the capacity for transmitting words. To utilize such large capacity requires that the cable be operated in a number of separate channels, each used as an individual unit; and since there were more circuits than were needed for the company's use, two in this cable to Horta were leased to another company.

Cables similar in design but embodying, in succession, still further improvements were laid between New York and Penzance, England, and between Newfoundland and Horta. Each of the three special alloy cables can transmit a total number of words equal to the combined capacities of the company's seven cables of older design. The cable between Newfoundland and Horta, while utilizing the new alloy, was designed by the engineers for simultaneous operation in both directions (duplex), and it has been so operated at a speed of 1,400 letters per minute each way, establishing the highest record thus far for any transoceanic cable.

While the use of permalloy is open to all, thus far, Western Union alone of the transatlantic cable companies has laid cables of this unique design, and the economies in operation resulting from their use successfully meet competition between North America, Great Britain, and Europe.

How cables are sent and received. The average man's idea of how cablegrams are sent and received is even more vague than his thoughts regarding the transmission of telegrams. The operator sending a cablegram copies the message on a machine with a typewriter keyboard, just as a stenographer would, and the machine perforates a paper strip. The paper strip then passes through an automatic transmitter. The holes in the perforated paper correspond to the dots and dashes which are transmitted directly from the tape into the cable.

Almost instantly, the signals are recorded on a tape at the distant

end of the cable and appear in ink in the form of a wavy line on a strip of paper which passes slowly in front of the receiving operator. The operator deciphers this wavy line as easily as you can read this line of type and types the message on a standard cablegram blank.

The machine which receives the signals from across the ocean and automatically marks a line on the tape is a siphon recorder. To make dashes, it dips below the center line; to make dots, it runs above the line. The siphon writing the signal is a hollow glass tube the size of a hair, operating as a pen and responsive to the electrical impulses received through the cable. As low as eight or ten volts will operate a cable across the Atlantic Ocean.

Through engineering skill, the multiplex has been adapted to cable use. Now the newest Western Union cables are operated by automatic printers. Depressing a key at the sending end causes the transmission of impulses which automatically select the corresponding letter and print it at the receiving end.

Western Union Organization Abroad

The Western Union operates offices in 15 cities in Great Britain and Ireland and also conducts wire branch offices located in convenient sections in London. There one finds a complete Western Union organization patterned after its organization in the United States, including the khaki-clad Western Union messengers.

The company has offices in Paris and Havre, served by direct cable from New York, and in Antwerp and Brussels. It maintains its own office in Amsterdam. In Germany, it is associated with the Deutsch-Atlantische Telegraphengesellschaft (DAT), whose submarine cables join those of the Western Union at the Azores. Direct service is provided between New York and Emden. At that point, the DAT is provided with land-line wires to the principal industrial and manufacturing centers in Germany. In Italy, it is associated with the Italcable Company, whose system connects with Western Union at the Azores. The Italcable Company also maintains offices in the principal cities in Italy.

Western Union operates a combination of land-line and submarine cables to Havana, where the company's staff is housed in its own building. Direct service from New York, through Havana, is established with Santiago, Cuba, Kingston, Jamaica, and San Juan, Puerto Rico.

The company operates land-line submarine service from New York to Bridgetown, Barbados, where a through connection is had with the Western Telegraph Company, serving all countries on the South American continent.

The company's submarine cable system totals 30,312 nautical miles. It controls and operates the Mexican Telegraph Company, whose systems extend from Galveston, Texas, through the Gulf of Mexico, serving Tampico, Vera Cruz, Mexico City, and Salina Cruz on the West Coast. In Canada, the company has contractual relations with the Canadian

National Telegraphs by which that company originates and terminates traffic for the Western Union system.

The Association of Radio, Cables, and Land Lines

Consideration of radio is not within the scope of this work, but recent developments in the coördination of international radio channels, cables, and land lines make a brief review necessary.

A working arrangement for the coördination of the land lines and radio, calculated to strengthen greatly the lines of quick communication between the United States and 30 other nations, was announced September 22, 1931, by the Western Union Telegraph Company and R.C.A. Communications, Incorporated.

Through this arrangement, R.C.A. Communications has gained the use of terminal facilities for the collection and distribution of its traffic which it had lacked, and Western Union has gained in having available R.C.A. radio circuits to 30 countries in Europe, Africa, Central and South America, and the West Indies to augment its cables in handling the vast traffic for those regions which it collects through its 25,000 offices

The arrangement is limited to a working agreement and involves no unification of properties or personnel of the two companies, which retain their competitive status where the two services overlap. It is similar to the arrangements which have existed for many years between the Western Union and R.C.A. Communications, Incorporated, covering the delivery and pickup of trans-Pacific traffic, and with the Radiomarine Corporation of America, another R.C A. subsidary, for the land collection and delivery of messages to and from ships at sea. All incoming messages over the Radio Corporation's vast network of wireless circuits are now turned over to Western Union for delivery, except at those points served by the Radio Corporation's own offices. Those points are New York, Boston, Washington, San Francisco, Philadelphia, Camden, Baltimore, Chicago, Detroit, New Orleans, Los Angeles, and Seattle, where the radio company handles its own messages. Correspondingly, Western Union offices accept outgoing radiograms for transmission via R.C A.

Many of the R.C.A. circuits go to countries remote from the transatlantic cable terminals, and through its traffic connections, the company brings in a large volume of communications from those countries. It had been handicapped in its disposition of this traffic by the paucity of its terminal facilities within the United States.

Western Union, on the other hand, greatly strengthened its competitive position through the delivery of incoming radiograms, and its close association with R.C.A. Communications, Incorporated, under the arrangement placed it in a position to supplement its ten high-capacity cables across the Atlantic with the wireless service whenever it could be employed, especially in the handling of communications to countries not served by direct cables.

The working arrangement between the radio and telegraph companies involves no unification of properties or personnel. It merely extends the scope of their previous traffic agreements.

34

The Telephone Industry

Development of the Industry

Early history. With the invention of the telephone came the dawn of a new era of business civilization, a new type of civilization which not even the inventor himself had dreamed possible; and it is safe to predict that, if the telephone industry ceased to exist today, through some unknown circumstances, American business virtually would be at a standstill.

The credit for making possible this new commercial civilization rightly belongs to the inventor of the telephone, Alexander Graham Bell. A resumé of his early life follows:[1]

> Alexander Graham Bell was born in Edinburgh, Scotland, March 3, 1847. He received his early education at McLauren's Academy and the Royal High School in Edinburgh; attended lectures on classical subjects at Edinburgh University for one year; took a course in anatomy at the University College, London; and matriculated as an undergraduate of the London University. He also received at a very early age training in music from Signor Auguste Benoit Bertini, and after Bertini's death, his musical education was carried on by his own mother following the Bertini method.

In 1865, Bell took up the study of electricity and later endeavored to transmit sound vibrations by means of electromagnets.

Both his older and younger brothers died of tuberculosis, which caused Bell's father to give up his connections in London and emigrate to Canada in 1870. In 1872, he came to Boston, where he opened a school of vocal physiology for deafmutes.

During the next 3 years, Bell carried on extensive experiments with telegraph instruments and discovered that variations in sound vibrations could carry over a telegraph line. This discovery was the birth of the telephone. Bell designed the piece of crude equipment and instructed Thomas A. Watson, one of his shop mechanics, to make it.

"On June 3, 1875, Watson built the first electric speaking telephone in the world, making every part of the instrument with his own hands."[2] On March 10, 1876, Bell spoke, and Watson heard the first complete

[1] From F. L. Rhodes, *Beginning of Telephony* (New York: Harper & Brothers), p. 1.
[2] *Ibid.*, p 24.

sentence ever transmitted by the telephone; it was, "Mr. Watson, come here, I want you." Bell had discovered the principle of telephony and, during his earlier experiments, stated: "If I could make a current of electricity vary in intensity as the air varies in density during the production of sound, I should be able to transmit speech telegraphically."

Although numerous adaptations of the variable resistance transmitters have been produced, one must not overlook the fact that the Alexander Graham Bell liquid transmitter, built on the theory of varying electrical intensity, was the first variable resistance transmitter ever produced and that its principles are still used in the practice of telephonic transmission.

Like all other major inventions, the telephone has many claimants to its invention. It is true that many persons had worked on the theory of transmitting the human voice over wires, but none had developed a practical solution to the problem. In 1854, a Frenchman by the name of Charles Bourseul published an article in which he set forth a hypothesis for the electrical transmission of speech. Again, in 1857, an Italian named Antonio Meucci, living on Staten Island, New York, devised a system that he believed could be used for transmitting the human voice by wire and made several attempts to obtain patent rights on it, but his idea never proved practical because it was an acoustic telephone and not an electrical one. The acoustic telephone operates by direct physical impulse and works very well only over a short distance. Alexander Graham Bell, on the other hand, discovered how to use electricity in the transmission of speech. By physical impulse, the voice travels through the air, as in ordinary talking, singing, or yodeling, at a speed of about 1,100 feet per second; through the medium of a string or metal wire, maybe a little faster. By electricity, the voice goes at the rate of 185,000 miles per second. This was the basic element in Bell's invention which was in no way a development of the acoustic telephone. Another attempt in 1860 was made by a German, Philipp Reis, who utilized the Bourseul method and who was successful in transmitting sound of a constant pitch, but his device was not adapted for continuous speech. While Bell was carrying on his experiments on the development of the telephone, many other experimenters in the United States were working on the same idea; in fact, Mr. Elisha Gray filed a caveat in the United States Patent Office claiming that he was about to invent the electrical transmission of the human voice only a few hours after the Bell patent application had been filed, on February 14, 1876.

Elisha Gray was one of the prominent inventors of the latter half of the nineteenth century. He was thorough and systematic in his researches and experiments. His great invention was the multiple telegraph. While working on that, he gave some time and interest to the possibilities of transmitting speech by electricity. He succeeded in transmitting musical tones, but that was a very simple matter compared with the transmission of the extremely complicated overtones of speech, which require an entirely different kind of electric current from the make-and-break current of telegraphy.

Alexander Graham Bell had invented his telephone on June 2, 1875, which was 9 months before Gray filed his caveat, and Bell then had a patentable article. In order to have his invention patented at the same time in England and in America, Bell delayed filing his application until February 14, 1876. The technical difference between the two is important. A caveat serves notice on the Patent Office that the inventor expects to invent something, whereas an application asserts that the invention has already been completed.

Daniel Drawbaugh, a mechanic living at Milltown, Pennsylvania, also claimed the initial invention of the speaking telephone long before Bell His claim dates back to 1867, but the courts did not uphold it. Professor Amos E. Dolbear and many others made similar claims, which caused a prolonged period of litigation and resulted in a decision pronouncing Alexander Graham Bell the original inventor of the telephone.

First practical use. Thomas Sanders and the Honorable Gardiner Greene Hubbard had given liberal financial aid to Bell during his experimentation with the telephone, and there was a gentlemen's agreement between them that all patents arising from Bell's inventions would be owned equally. Telephones were at first rented in pairs to individuals for local use. This lowly beginning of telephone communication, from which emerged the enormous network of wires from coast to coast of our present system, consisted of a piece of iron wire connecting both instruments with the return circuit grounded. Switchboards were unknown, and communication was uncertain and poor at best.

The first switchboard. The first telephone switchboard came into existence in May, 1877.

> A young man named E. T. Holmes, who was running a burglar-alarm business in Boston, proposed that a few telephones be linked to his wires. Hubbard was quick to seize this opportunity and at once lent Holmes a dozen telephones. Without asking permission, Holmes went into six banks and nailed up a telephone in each. Five banks made no protest but the sixth indignantly ordered that "Playtoy" to be taken out. The other five telephones could be connected by a switch in Holmes' office, and thus was born the first tiny and crude telephone exchange.[3]

Steps in the development of national telephone service. The agreement between these three men—Sanders, Hubbard, and Bell—created an informal partnership out of which evolved a company whose stock was divided equally among them.

> On February 2, 1878, the New England Telephone Company, a Massachusetts corporation (not the present New England Telephone and Telegraph Company), acquired from Mr. Hubbard, as trustee, territorial rights, under Bell's four patents, for the New England states. On July 20, 1878, the rights in these patents for the rest of the country were assigned by Mr. Hubbard, as trustee, to a new corporation, the Bell Telephone Company. These two interests—one covering the New England States, the other the remainder of the United States—

[3] H. N. Casson, *The History of the Telephone* (Chicago: A. C. McClurg & Company), p. 53.

were soon united by purchase; and on March 20, 1879, the New England Telephone Company and the Bell Telephone Company both assigned to a new corporation, the National Bell Telephone Company, their rights under two of Bell's patents, namely, those covering his harmonic telegraph system and the receiving instrument designed for use with it.

The American Bell Telephone Company was chartered on March 19, 1880, and acquired by assignment and licenses all patent rights belonging to the Bell interests previously existing.[4]

Mr. Hubbard, president of the newly formed company, was successful in obtaining the services of Mr. T. N. Vail as general manager to carry on business activities. Mr. Vail formulated sound business policies, methods, and procedures, and refused to consider seriously the many schemes to sell the telephone rights. It is interesting to note that these basic policies are fundamental in the present-day policies of the American Telephone and Telegraph Company. Mr. Vail induced many of his friends to invest money in the stock of this new company, which had 12,000 phones in service. Through his efforts, he procured $450,000, which constituted the capital of this new company. In 1883, Mr. Vail ordered an experimental long-distance telephone line to be installed between Boston and New York. The wire used was made from hard-drawn copper and was the first successful long-distance overhead telephone line; it covered a distance of 235 miles. Mr. Vail worked diligently on the problem of a satisfactory telephone wire, with the result, in 1885, of the successful construction of an experimental telephone line, consisting of a number of wires of various sizes, between New York and Philadelphia.

The next important step toward the attainment of a national telephone service was the organization of the American Telephone and Telegraph Company, in 1885. This company was formed to build and operate long-distance lines to interconnect the regional companies that had developed by merger and growth from earlier licensed companies that were giving local service.

To realize the ideal universal telephone service, it became increasingly important to extend the long lines even further, to carry on continuous investigation for the practical development of the telephone art, to make further progress toward the standardization of apparatus, equipment, and methods, and to centralize administrative functions as far as possible in the interest of efficient and economical service. In 1900, therefore, the American Telephone and Telegraph Company absorbed the American Bell Telephone Company, becoming the central, or headquarters, company of the coördinated federation that is known as the "Bell system."

After the basic telephone patent expired, independent telephone companies, not connected with the Bell system, were organized in large numbers. Many of these companies introduced telephone service in small communities where there was no Bell telephone service, but some entered into competition in communities where Bell companies were

---

[4] Rhodes, *op. cit.*, p. 50.

already operating. Great public dissatisfaction resulted from the inconvenience and unnecessary expense caused by telephone competition (since one had to subscribe for both telephone services or else be out of touch with many of the telephone users in the community). In many cases these inconveniences were eliminated by a consolidation of the competing telephone services; in others, physical connection was established between the lines of the Bell system and those of the independently owned telephone companies.

From wires to cables. The first telephone lines were overhead, stretching from pole to pole and from building to building. As the number of telephones steadily increased, the number of these overhead wires also increased, until a regular network more or less blotted out the sky for many cities. Beside this, snow and sleet storms caused havoc to telephone communications and also greatly increased the cost of telephone-line maintenance. However, the never-ceasing research activities of the diligent telephone engineers found a solution to this problem by installing an underground system of conduits and cables.

By January 1, 1886, there were only 3,417 miles of wire underground in the Bell system out of a total wire mileage of 155,791. This underground mileage could be contained in less than 1 mile of modern 1,800-pair cable.

In 1887, the successful introduction of the twisted pair, underground conductor paved the way for the extensive use of cables. In 1902, the application of the loading coil, together with other improvements, permitted the installation of a loaded cable between New York and Newark, New Jersey In 1905, a loaded cable, 20 miles long, extended from New York in the direction of Philadelphia. In 1906, an underground cable, 90 miles long, was successfully operated between New York and Philadelphia.

Early in 1909, a sleet storm swept the Atlantic seaboard, paralyzing communication and isolating the capital at the time of President Taft's inauguration. The next morning the chief engineer (J. J. Carty) of the Bell system received from Theodore N. Vail, then president of the American Telephone and Telegraph Company, a note beginning: "Put those wires underground. I know that the present state of the art of telephony does not make such wire-burying possible. But experiment. . . ." The Bell engineers did experiment, and by 1911 they had designed an underground cable capable of giving satisfactory conversation between Boston and Washington. By 1912, a cable connection had been laid between Washington and New York. By 1913, the cable had been extended between Washington and Boston, a distance of 455 miles. This was several times longer than any other underground line in the world at that time.

> The best idea of the enormous saving in space which cable effects is given by some figures relating to New York City. At the corner of Seventh Avenue and 36th Street there are more than one hundred thousand lines underground. This vast number of wires, if placed upon a single overhead line, would require poles four miles high If the poles

> were only as high as the Woolworth Tower, the streets would be roofed in by twenty-five such gigantic lines and a veritable canopy of copper.
>
> Ever since the first underground cables were installed under city streets, . . . the technique of making telephone cables has advanced steadily. . . . Together with the increase in the enormous number of telephone lines that can be placed in a single cable has gone a corresponding reduction in the size of copper wire required for each circuit.[5]

Growth of the Bell system. A study of the statistical data in Table I will give a perspective of the phenomenal growth of the telephone industry. In 1900, the plant investment of the Bell system in the United States was about $181,000,000; on December 31, 1939, it amounted to $4,590,510,000. This growth becomes more evident if one examines the increase in the number of telephones and the increases in mileage of telephone wires put into service during the past 30 years.

Organization of the Bell System

The structure of the Bell system is simple. It is comprised of a closely integrated group of companies associated together for the purpose of providing a single unified telephone service in the United States. Basically the system, developed during a period of more than 50 years, comprises the following: (1) the American Telephone and Telegraph Company (the parent company), which is also the headquarters organization; (2) the principal telephone-operating subsidiaries of the American Telephone and Telegraph Company, now 24 in number, and 2 noncontrolled telephone companies, each of these 26 companies serving a part of the United States; and (3) the long-lines department of the American Telephone and Telegraph Company, by which the telephone lines of these operating companies and their connecting companies are united in a national service and are linked with telephones in other countries and on certain ships at sea.

Closely associated with this group are: (1) the Bell Telephone Laboratories, Incorporated, which carries on for the Bell system the scientific research and development work essential to the continuous improvement and cheapening of telephone service; and (2) the Western Electric Company, which takes care of the manufacturing and purchasing for the Bell system.

Besides the Bell operating companies, there are about 6,500 independently owned companies, together with more than 25,000 rural lines and systems, which are connected with the Bell-system lines for the interchange of toll calls, thus making possible an intercommunicating telephone system for over 70,000 cities, towns, and rural communities in America.

The American Telephone and Telegraph Company is often called the "headquarters company of the Bell system." The regional operating companies which it owns in whole or in part are responsible for telephone

---

[5] From F. W. Wile, *A Century of Industrial Progress* (New York: Doubleday, Doran & Company, Inc.), p. 449.

Table I

BELL SYSTEM STATISTICS

	Dec 31, 1910	Dec. 31, 1920	Dec. 31, 1925	Dec. 31, 1930	Dec. 31, 1935	Dec. 31, 1939	Increase Decrease[a] During 1939
Number of Telephones[b]	5,883,056	8,133,759	11,909,578	15,187,296	13,573,025	16,535,804	774,709
Number of Central Offices	4,933	5,767	6,147	6,639	6,896	7,001	26
Miles of Pole Lines	282,877	362,481	394,529	428,212	407,454	397,202	*2,166*
Miles of Wire:							
In underground cable	6,017,000	14,207,000	27,769,000	45,116,000	47,639,000	52,041,000	1,258,000
In aerial cable	2,870,000	6,945,000	12,835,000	23,777,000	26,425,000	28,910,000	838,000
Open wire	2,755,000	3,711,000	4,339,000	5,231,000	4,562,000	4,586,000	*4,000*
Total	11,642,000	24,863,000	44,943,000	74,124,000	78,626,000	85,537,000	2,092,000
Average Daily Telephone Conversations (for year ending Dec 31)[c]	22,284,000	33,125,000	50,141,000	64,034,000	60,290,000	73,802,000	3,906,000
Total Plant	. . .	$1,373,802,000	$2,566,809,000	$4,028,836,000	$4,187,790,000	$4,590,510,000	$101,432,000
Operating Revenues (for year ending Dec. 31)	. . . .	$ 446,115,000	$ 737,560,000	$1,075,228,000	$ 919,116,000	$1,107,188,000	$ 54,530,000
Taxes (for year ending Dec. 31)[d]	. . . .	$ 27,743,000	$ 58,113,000	$ 84,732,000	$ 94,507,000	$ 156,309,000	$ 11,196,000
Number of Employees[e]	120,311	228,943	292,902	318,119	241,169	259,930	2,487
Number of A. T. & T. Co. Stockholders	40,381	139,448	362,179	567,694	657,465	636,771	*10,111*

[a] Decreases shown in italics.

[b] Excludes private line telephones numbering 77,495 on December 31, 1939. Including telephones of about 6,500 connecting companies and more than 40,000 directly and indirectly connecting rural lines, the total number of telephones in the United States which can be interconnected is approximately 20,750,000.

[c] For the year 1939 there were approximately 71,200,000 average daily local conversations and 2,602,000 toll and long-distance conversations, an increase of 5.6 and 5.5 per cent, respectively, over the year 1938.

[d] Excludes taxes charged construction (amounting in 1939 to $2,596,800).

[e] In addition, the Western Electric Company, Incorporated, and the Bell Telephone Laboratories, Incorporated, had 37,197 employees on December 31, 1939.

service in the communities where they are established. Their function is to study and to serve local needs and requirements, present and future. Their policies and practices are shaped to this end. They are state or regional enterprises, operated and managed by local people intimately identified with the activities of the communities where they live and work. Every one of their exchanges is a local institution. Each company is organized and equipped to meet the operating telephone problems within its area, both local and long-distance.

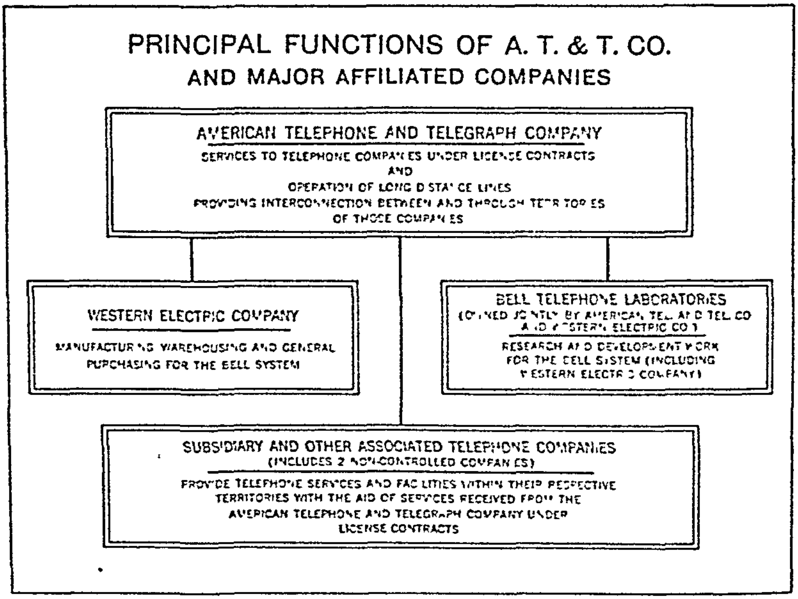


Fig. 1.

These regional companies operate under state laws and, as to service within the states, are subject to regulation by state commissions. They, as well as the American Telephone and Telegraph Company, are subject as to certain matters to regulation by the Federal Government.

Regional companies. The problem of meeting the service needs of local communities varies with the character and activities of the communities. It is the specific responsibility of the local telephone organizations and requires the complete and constant attention of the regional companies.

There are also general problems common to all the companies. In order that these may be handled economically and efficiently, the regional companies contract with the American Telephone and Telegraph Company for centralized services relating to them. This contractual relationship dates back to within a few years of the telephone's invention. It is an outgrowth of the original licensing arrangement whereby the first telephone companies secured instruments for the use of their sub-

scribers. It was founded on the necessities of the business. It still exists for the same reason.

Through this arrangement the regional companies, in effect, employ the headquarters company to do for them the things which can be done better and more economically by a centralized organization.

General-staff service. To meet this responsibility, the American Telephone and Telegraph Company has organized itself to perform services relating to engineering and operation, finance, accounting, and law, and to give such other assistance to the regional companies as may be helpful to them in conducting their business.

A few illustrations will show how it functions under this arrangement. To furnish financial assistance is one of its important services, particularly in periods of rapid growth, when vast sums are needed for plant additions and replacements to meet the demands of the public for service.

Another service of the utmost importance is that enabling the regional companies to utilize every improvement resulting from the research and experimentation of its scientific workers in the Bell Telephone Laboratories and to keep track of scientific achievements in the world at large that might be beneficial to the telephone industry.

Thousands of patents covering the results of Bell-system research activity are owned by the headquarters company for the benefit of all the operating units of the Bell system.

These results, of course, are expressed physically in the apparatus and equipment that the regional companies use to give service. They have been of enormous importance in improving the quality and reducing the cost of their service.

But the problem of apparatus is only one of the multitude of problems that the Bell regional companies share in common. There is a best way of doing everything, and the application of this best way to the innumerable details of operation is what they are constantly seeking.

Another service, therefore, that the regional companies engage the American Telephone and Telegraph Company to provide, though classified as "telephone engineering," is so broad in its scope as to include the entire range of construction, operation, maintenance, and business practices. No single company could afford to make these studies for itself.

New ideas for improved equipment and operating practices are constantly being studied by the staff of the headquarters company and, from time to time, are suggested by men in the operating companies. These new ideas are developed and tested, and the resulting improvements are spread over the whole Bell system.

The cost of this research and advisory service is more than the headquarters company receives for rendering it. The American Telephone and Telegraph Company functions in the manner of a general staff, ready to provide expert assistance in solving any new problem that may arise, but is principally occupied with studies and developments that will anticipate problems.

One department of the headquarters company, for example, develops a new technique for the system's construction forces—such as a new and

more economical method of laying cable and conduit or details for installing armored cross-country cable underground without conduits. Another studies the system's collective experience with buildings and equipment in order that the knowledge gained from this experience may be applied to central-office design. A third group sets up practices for the design of the plant from a transmission standpoint to insure that any subscriber of the Bell system can at all times talk satisfactorily to any other subscriber and, furthermore, that this be achieved at the least possible overall cost. Another, specializing in traffic matters, perfects operating practices that cut many seconds from the time required for handling calls and that further improve their accuracy. Another helps the regional companies to develop business practices and office routines; it studies markets, and assists in formulating promotional plans and the carrying forward of a great number of other necessary functions. Still another department advises the companies as to the most efficient methods involved in accounting work and in the statistical analyses of the results of operation needed for local administrative purposes. Thus it is possible for the Bell system to give the best, the most economical, and the most comprehensive telephone service in the world.

Ownership and physical assets. The total number of owners of Bell-system securities is about 750,000. The American Telephone and Telegraph Company alone was owned on December 31, 1939, by 636,800 stockholders, including about 74,000 stockholders who are Bell-system employees.

Of the total number of stockholders, 359,000, or 56 per cent, owned from 1 to 10 shares each; while 611,000, or about 95 per cent, owned less than 100 shares each. The average number of shares of the American Telephone and Telegraph Company's stock held per stockholder was 29. No one stockholder owns as much as 1 per cent of the total stock.

The vast amount of equipment and the large trained organization employed to maintain efficient telephone service to meet all the telephone requirements of a nation of over 130,000,000 people are shown by the following comparisons.

Poles. There are more than 15,000,000 telephone poles, enough to build a solid transcontinental fence 30 feet high from New York to San Francisco. Fifteen million poles represent a forest of over 800 square miles in extent.

Wire. There are more than 83,000,000 miles of exchange and toll wire. This is enough to reach from the earth to the moon and back again more than 170 times.

Cable sheath. This amounts to more than 2,000,000,000 pounds of lead alloy. It would fill 20,000 50-ton freight cars, making a train 150 miles long.

Underground conduit. There are more than 625,000,000 duct feet of underground conduit. This would go through the earth about fifteen times from pole to pole.

Telephones. There are more than 15,900,000 Bell-owned and about 4,150,000 Bell-connected telephones, representing in the aggregate 49 per

cent of the total telephones in the world. Practically any two of these 20,000,000 telephones may be interconnected. In addition, service is available between them and about 18,000,000 other telephones in North America, Central America, South America, Europe, Asia, Africa, and Australia, as well as Hawaii, the Philippines, Japan, and other island groups.

Buildings. The Bell-system buildings number about 3,200, not including some 5,400 leased properties, and represent an investment equal to the real-estate valuation of some of our larger cities. These building spaces, comprising central offices, repeater stations, garages, warehouses, shops, and office buildings, are of all sizes, from one room to a 30-story building covering a city block. They are dotted all over the country in a variety of locations, ranging from isolated sections through residential areas to downtown sites.

Since 1920, the Bell system has spent on net plant additions alone over $3,000,000,000, or enough money to build seven Panama Canals and six Holland Vehicular Twin Tunnels. It is interesting to note that the investment in the Bell-system plant has more than tripled during this period.

Motor vehicles. Over 20,000 motor vehicles are employed by the Bell system. If parading in single file, they would make a column over 150 miles in length.

Telephone directories. For the use of telephone subscribers, the Bell system prints and distributes each year an aggregate of 27,000,000 copies of about 2,100 different directories. The printing of these directories requires the use of about 30,000 tons of paper.

Personnel

Behind the telephone instrument is a hidden world peopled with thousands of men and women who are engaged in a vitally important public service but who are rarely seen by the public they serve.

Of the men in the telephone service, the telephone user sees something—the installer, the repairman, linemen on a country road, a cable gang working in a city street. Of the women, he sees almost nothing. Through his telephone receiver, as through a half opened door, there come to him the trained voices of his telephone operators, each reflecting courteous efficiency, pride in a worth-while work, devotion to duty. By these voices and by them alone, America knows the young women who, guarding a web of wires which crosses and recrosses the continent, have helped to transform a commonwealth of widely separated states into a single vast community. And there are thousands of women who, in other capacities, help to maintain the telephone service.

The two men who comprised the telephone industry at its beginning (1876) have been increased to a vast army of more than 350,000 persons in the United States alone. Of this vast army, 297,100 are in the Bell organization, including the operating companies, the Western Electric

Company and the Bell Telephone Laboratories. The total payroll for 1939 amounted to $570,151,000.

More than half of the employees of the Bell Telephone Companies at the beginning of 1938 were women. Their average age was 31; their average length of service, over 10 years. The average age of men employed in the telephone companies was about 38; their average length of service, nearly 15 years.

Employees' pension and other employee-benefit plans. The plan for employees' pensions, disability benefits, and death benefits has now been in operation for 27 years. The plan is noncontributory, all the costs being paid by the companies. Payments thereunder, except for service pensions, are made directly on a pay-as-you-go basis, while service pensions are provided for in advance on an actuarial basis, with payments made periodically into pension trust funds, from which the trustee pays the service pensions. At the end of 1939, these trust funds for the Bell system, including the Western Electric Company and the Bell Telephone Laboratories, aggregated $268,627,668, which is irrevocably dedicated to service-pension purposes.

The Bell-system plan has, from its inception, provided that pensions payable by any Governmental agency shall be deducted from pensions otherwise payable under the plan. Following the enactment of the Federal Social Security Act of 1935, all employees were advised that no change was contemplated in the plan as a result of the act, except that, if the latter remained in effect unchanged until 1942, when pensions became payable under the act, it was expected that the provision for deducting all of the Government pension from a pension otherwise payable under the plan would be changed to provide that only one half of the pension paid under the Social Security Act would be deducted. This proposed change gave recognition to the fact that one half of the direct-tax contributions under the Social Security Act for old-age benefits is paid by the employee.

The 1935 Social Security Act was amended in 1939, and monthly Federal old-age benefits became payable beginning January 1, 1940, instead of 1942, to eligible persons 65 years of age or older. The Bell-system plan has therefore been amended, effective January 1, 1940, to carry out the intent of the above-mentioned announcement to employees made in 1936. The amended plan provides that the service pension payable to a retired employee after he has attained the age of 65 will be reduced by one half of the "primary insurance benefit" to which he is entitled under the Social Security Act Amendments of 1939. The "primary insurance benefit" computed for the purpose of this adjustment will be based solely on Bell-system wages and employment.

The sickness-disability-benefit schedule in the plan, which in the past has provided for maximum benefits of 13 weeks' full pay and 39 weeks' half pay to employees with 10 or more years of service, was also changed, effective January 1, 1940, by increasing the full-pay benefit periods for employees with 15 or more years of service. Under the new schedule, employees will receive 26 weeks' full pay and 26 weeks' half pay

for 15 to 20 years of service, 39 weeks' full pay and 13 weeks' half pay for 20 to 25 years of service, and 52 weeks' full pay for 25 or more years of service. The provisions covering accident-disability benefits have been correspondingly modified, so that, for cases originating on and after January 1, 1940, the full-pay periods for employees of 15 or more years of service are the same as in the new schedule for sickness benefits.

The Bell system, including the Western Electric Company and the Bell Telephone Laboratories, had 8,930 retired employees on the service-pension rolls at the end of the year 1939. The total amount of service pensions paid from the pension trust funds in that year was $7,645,000. During the same time pension accruals, actuarially determined, amounting to $17,589,000, or 3 1 per cent of the payroll, were paid into the pension trust funds.

Other payments made in 1939 under the plan were:

Sickness-disability benefits	$6,006,000
Accident-disability benefits	539,000
Death benefits	2,041,000
Disability pensions	444,000
Total	$9,030,000

During 1939, employees continued to make extensive use of the payroll-allotment plans maintained by the companies to assist them in accumulating savings in the form of life insurance, deposits in savings institutions, and United States Savings Bonds. These plans are entirely voluntary and the administrative costs are paid by the companies.

Through the insurance plans, employees can pay monthly premiums on life insurance or annuities by payroll allotments forwarded to insurance companies. Under these plans, 78,900 employees of the Bell system, including the Western Electric Company and the Bell Telephone Laboratories, at the end of 1939, were carrying standard life insurance amounting to $244,000,000. Premiums paid on this insurance during the year amounted to $7,842,000. Employees also carried some 6,300 annuity contracts, the premiums on which amounted to approximately $750,000 during the year.

Premiums amounting to $205,000 were also paid on United States Government insurance totaling $8,000,000, carried by 1,690 employees who are First World War veterans.

At the end of 1939, 21,250 employees were using the plans established in 1938 to invest in United States Savings Bonds. Payroll allotments made during 1939 toward the purchase of bonds totaled $2,660,000.

The plans for deposits in savings institutions of employees' selection were being used by 105,700 employees at the end of 1939.

Distribution of Telephones

There are more than 22,250,000,000 exchange messages and 800,000,000 toll messages over the Bell-system wires yearly. Including messages sent over the wires of other telephone companies, more than 28,000,000,-

000 exchange and toll messages are transmitted annually in this country, or about two conversations daily for every three persons—men, women and children—in the country. The Federal post office, which ranks next in point of number of service contacts, handles about 14,000,000,000 letters and postcards annually.

Public telephones form an important link in America's nation-wide telephone service. Located in hotels, railway stations, stores, and other public and semipublic buildings, they make telephone service available when one is away from the office or home—making it doubly a public service. Nowhere in the world is the use of the public telephone so common as in the United States.

The latest statistics available showing the distribution of telephones throughout the world relate to January 1, 1938. On that date, the United States, with about one twentieth of the world's land area, had nearly one half its telephones, or 19,453,000 of the 39,000,000 telephones then in use throughout the world.

On the basis of telephones per 100 population, the United States had over six times the telephone development of Europe as a whole, four times that of France, more than two and one half that of Germany, and more than twice that of Great Britain.

On January 1, 1938, New York City, with 1,623,117 telephones, had more telephones than any other city in the world. The number of telephones in this one American city was greater than the number in the whole of each foreign country in the world, with the exception of Germany and Great Britain.

On this same date, Chicago had more than twice as many telephones as Switzerland, Los Angeles almost two and one quarter times as many as the Union of South Africa, and San Francisco nearly three and one half times as many as British India.

Equally striking, in showing the superiority of the telephone development in the United States, are figures on the development of the less populated sections as compared with the urban centers. In the United States, places having less than 50,000 people were served on January 1, 1938, by 10.8 telephones per 100 population, as against 21.2 telephones per 100 population for communities of 50,000 population and over. In no other country was the telephone development of the smaller places as high as that in the United States. In fact, in many foreign countries, the development of the less populated regions is relatively so low that it is no exaggeration to say that their telephone service is confined largely to their principal cities. For example, London, on January 1, 1938, had about one quarter of the total telephones in Great Britain, and Paris had nearly one third of the total number in France. Even Germany, with its otherwise progressive rural communities, had 25 per cent of all its telephones concentrated in the four cities of Berlin, Cologne, Hamburg, and Munich.

In proportion to population, on January 1, 1938, New York had one third again as many telephones as London; Chicago, on the same basis, had more than twice as many as Berlin.

These figures indicate how large a place the telephone fills in the American mode of life. They reflect, too, the activity of the telephone companies in calling attention to the possibilities for maximum comfort and convenience afforded by adequate telephone facilities.

Fundamental Policies of the Bell System

In an address before the National Association of Railroad and Utilities Commissioners at Dallas, Texas, in 1927, and in successive annual reports to the stockholders, President Walter S. Gifford of the American Telephone and Telegraph Company restated the fundamental policies of the Bell system. These policies relate to the carrying out of the management's threefold obligations to its investors, to the telephone-using public, and to its employees, and are predicated upon the fact that there are over 625,000 stockholders of the American Telephone and Telegraph Company and nearly 300,000 employees of the Bell system, including the Western Electric Company and the Bell Telephone Laboratories, and that the Bell system owns more than three quarters of the telephones in the United States and connects with nearly all of the remainder, affording facilities for interconnection among 99 per cent of the telephones in the country and about 93 per cent in the entire world. The policies as laid down by President Gifford may be summarized as follows:

(1) The fact that the responsibility for such a large part of the entire telephone service of the country rests solely upon the American Telephone and Telegraph Company and its telephone-operating subsidiary companies imposes on the management an unusual obligation to the public to see that the service shall at all times be adequate, dependable, and satisfactory to the user.

(2) The fact that so large a share of the responsibility for meeting the telephone needs of today rests upon the Bell system implies that it must also be responsible for meeting the needs of the future. It has a peculiar obligation to carry on the research and experimentation necessary for the further development of the telephone art.

(3) The fact that the ownership of Bell-system securities is so widespread and diffused imposes an unusual obligation on the management to see that the savings of these hundreds of thousands of people are secure and remain so.

(4) The policy which recognizes these obligations to the telephone-using public, both of today and of the future, and to its investors recognizes equally the Bell system's responsibilities to its employees. It is and has been the policy and aim of the management to pay salaries and wages in all respects adequate and just, and to make sure that individual merit is discovered and recognized.

Obviously, the only sound policy that will meet these obligations is to continue to furnish the best telephone service at the lowest cost consistent with financial safety.

Earnings must be sufficient to assure the best possible telephone service

at all times, the further development of the art, and the continued financial integrity of the business. Earnings that are less than adequate must result in telephone service, in the present and in the future, that is something less than the best possible. Earnings in excess of these requirements must either be spent for enlargement and improvement of the service furnished, or the rates charged for the service must be reduced.

This is the basis of the fundamental policy and purpose of the Bell system—the most telephone service and the best, at the least cost to the public, consistent with these obligations.

Research and Development in the Industry

The importance of scientific research in the development of the telephone early became apparent. The Bell-system pioneers who laid the foundation upon which America's telephone system was to be erected found that they had to create a new art. Nothing then existing provided a precedent for what they were to undertake. Isolated theories and unrelated facts were all that other science could contribute, and these had to be wrested by the new art from its older sisters by patient research and experimentation. Hard-earned advances blaze the trail of telephone progress, each problem successfully solved being a monument to untiring effort.

The staff of the Bell Telephone Laboratories comprises over 4,500 people, of whom more than half are scientists, investigators, and technical specialists who continually carry on research and experimentation in the fields of the two fundamental problems of electrical communication—the electrical transmission of intelligence and the development of the channels for such transmission. Numerous collateral studies relating to the general science and art underlying electrical communication and allied subjects are also carried on. This research work has been of inestimable value in extending the scope of electrical communication service and in improving it in economy, efficiency, and dependability. The visible results are in the switchboards, cables and wire lines, loading coils, repeater tubes, and telephone instruments—in the hundreds of physical details that combine to form the intricate plant necessary for the quick and clear transmission of speech. The invisible results are apparent to telephone users in the constantly improving quality of service. Through the research work carried on for the Bell system, new metal alloys have been discovered, new designs in apparatus have been achieved, the size and consequently the cost of numberless items of equipment has been reduced. Hundreds of millions of dollars have been saved the telephone users of the nation.

In some six decades of telephone research, the telephone engineers have overcome one by one the barriers of speech transmission. From the very beginning, the progress of the art has been marked by epoch-making advances due to inventions and improvements in apparatus and equipment. Some of the more notable achievements in the development of the art have been as follows:

(1) The development of the switchboard, without which no interconnecting group of telephones would be possible, and which was the beginning of the telephone-exchange system.

(2) The discovery of the process of hardening copper wire and its application to telephone circuits, improving transmission and making long-distance, open-wire telephone circuits possible.

(3) The substitution of a pair of wires for a single wire with ground return, thus very much reducing the disturbances caused by adjacent power circuits or other telephone circuits and greatly improving transmission.

(4) The multiple switchboard, making possible the expansion of the exchange system by providing positions at the switchboard for a large number of operators, each answering the calls on a certain number of subscribers' lines. Because of the duplication of all the subscriber-line terminals at each section of the switchboard, each operator is able to connect the calling subscriber with any other subscriber in the same central office.

(5) Successive improvements in the design of the telephone instrument *that have not only increased its efficiency as a means of communication* but have given it a more attractive appearance. The early "box" telephones were superseded by various types of wall and desk sets. Now the convenient and graceful hand telephone is made available, with or without the dial.

(6) The transposition of telephone circuits, thereby minimizing the interference of other telephone circuits and of electric-light and power wires.

(7) The development of the underground cable, enabling the removal of pole lines from the main thoroughfares of the large cities; and the aerial cable, reducing the number of crossarms and the size of the poles.

(8) The phantom circuit, which is made possible by utilizing two physical telephone circuits to create a third independent circuit.

(9) Carrier-current telephony, in which the telephone current is combined with a high-frequency current, transmitting this combination over line wires and, at the receiving end, removing the high-frequency current and leaving the telephone current, making it possible to transmit simultaneously several telephone currents over a telephone circuit.

(10) The application of the repeater, or current amplifier, to long-distance circuits, further increasing the range of long-distance telephony; also, its application to overhead and underground cables, making it possible to extend greatly the use of cables in place of open-wire construction and allowing the use of smaller gauge wire. General improvement in speech transmission was also accomplished.

(11) The range of possible use of cable has been gradually increased until, by 1920, conversation was possible through 2,000 miles of cable. Methods have since been developed which will make conversation through 15,000 miles of cable practically as good as a conversation from one room to another in the same building.

(12) Improvements in the design and in methods of manufacture of

cables for local exchange use that have made it possible to increase greatly the number of wires which may be placed within a cable sheath of given size. By employing wires of smaller diameter, the maximum number carried in a single cable has been increased to 2,121 pairs.

(13) Development of radio telephony and of means for associating it with wire lines, making possible telephone service from the United States to a large number of countries overseas and to vessels at sea.

(14) Improvements in dial telephone apparatus and systems, enabling dial telephones to be used more advantageously in large metropolitan areas as well as in smaller cities and communities.

(15) The discovery of new magnetic alloys—permalloy, molybdenum permalloy, permendur, and perminvar. The first two have made possible a reduction in the sizes and a decrease in the cost of loading coils required for telephone cables and have brought about savings in many other types of telephone apparatus. Permendur, used in the receiver diaphragms of the latest type of handset, is responsible for a marked improvement in that instrument.

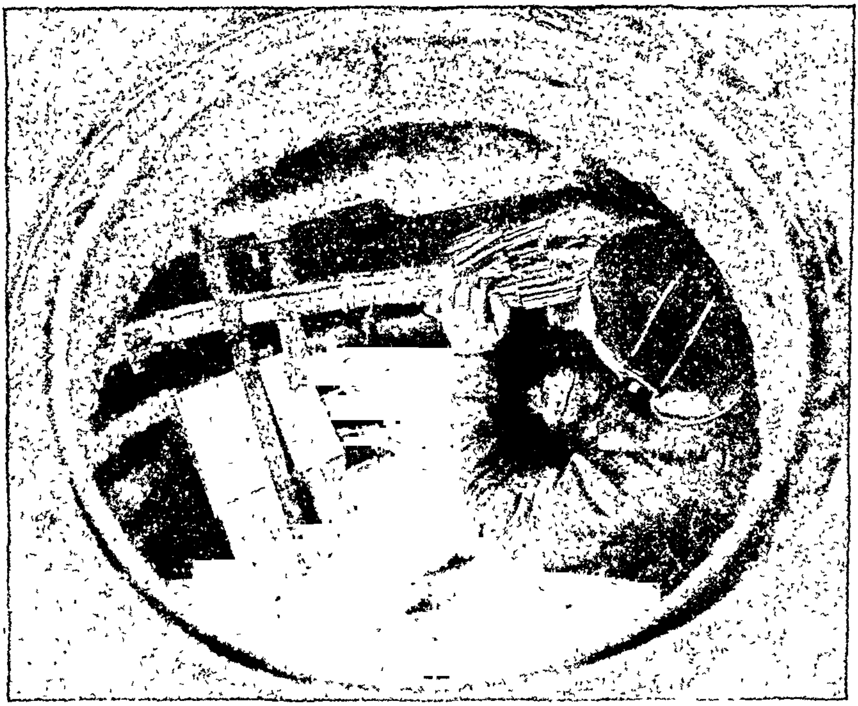
Advances in long-distance transmission. The cumulative effect of improvements and inventions in telephone apparatus and equipment is nowhere shown more strikingly than in the progressive advances in long-distance transmission that have been made from time to time.

In 1881, there was opened the Boston-Providence line, 45 miles long; in 1884, the New York-Boston line, 235 miles; in 1892, the New York-Chicago line, 900 miles; in 1911, the New York-Denver line, 2,100 miles, and in 1915, the New York-San Francisco line, 3,400 miles. In 1920, regular commercial radio-telephone service was established between Santa Catalina Island, about 30 miles out in the Pacific Ocean, and the mainland near Los Angeles, California, at the latter point making junction with the local and long-distance wires of the Bell system throughout the United States. In 1921, came the opening of the Key West-Havana submarine telephone cables, bringing all the principal places in the United States into communication with Havana and other important places in Cuba. In 1923, submarine telephone cable was laid connecting Santa Catalina Island with the mainland, superseding the radio-telephone service. In 1925, after 7 years of construction work, a stormproof cable, 861 miles in length, connecting New York and Chicago, was finished and put into service; and in 1926, it was extended to St. Louis. The 850-mile extension of the New York-St. Louis all-cable line to Dallas was opened for service in January, 1933. By means of this addition to the cable network, a direct New York-Dallas circuit about 1,850 miles long was established. Of cities in the United States of 50,000 or more inhabitants, 75 per cent are connected with the toll-cable network of the Bell system.

To the original Transcontinental Telephone Line, opened in 1915, have been added three other routes for coast-to-coast service. A southern route by way of El Paso and Los Angeles was completed in 1923. In 1927, a northern transcontinental line was completed and opened to

public service which, west of Chicago, passes through Minneapolis, Fargo, Bismarck, and on to Seattle. The fourth transcontinental line by way of Kansas City, Albuquerque, and Los Angeles has since been constructed to supplement the central and southern routes.

In 1927, service between points in the United States and the principal cities of Mexico was inaugurated by the ceremonies in which the presi-



Courtesy, New Jersey Bell Telephone Company

Fig. 2. A splicer at work in a manhole joining together two ends of big cable. Each of the many hundreds of strands must be connected to its proper mate The probe-like instrument in his right hand signals to him through his earphones when he has the right one. This device, known to telephone men as a "bluffy sniffer," enables him to locate any particular pair in a fraction of a minute, whereas the old method might require many minutes. Insulation of different colors also guides him by narrowing down the choice

dents of the two Republics exchanged greetings over a circuit connecting Washington, D. C., and Mexico City.

The Bell system's underground system. Of the Bell system's 83,000,000 miles of wire, 50,000,000 miles are enclosed in lead-covered cables in underground conduits, including about 6,800,000 miles of toll wire. Sixty-five per cent of the exchange wire of the Bell system is in underground cables. The exchange and toll underground cables are laid in more than 625,000,000 duct feet of conduits.

Bell engineers early discovered that the problem of speaking through long cables or over great distances could not be solved by increasing the power of the telephone instruments The fact that 1 mile of underground cable cuts down the transmission as much as about 30 miles of

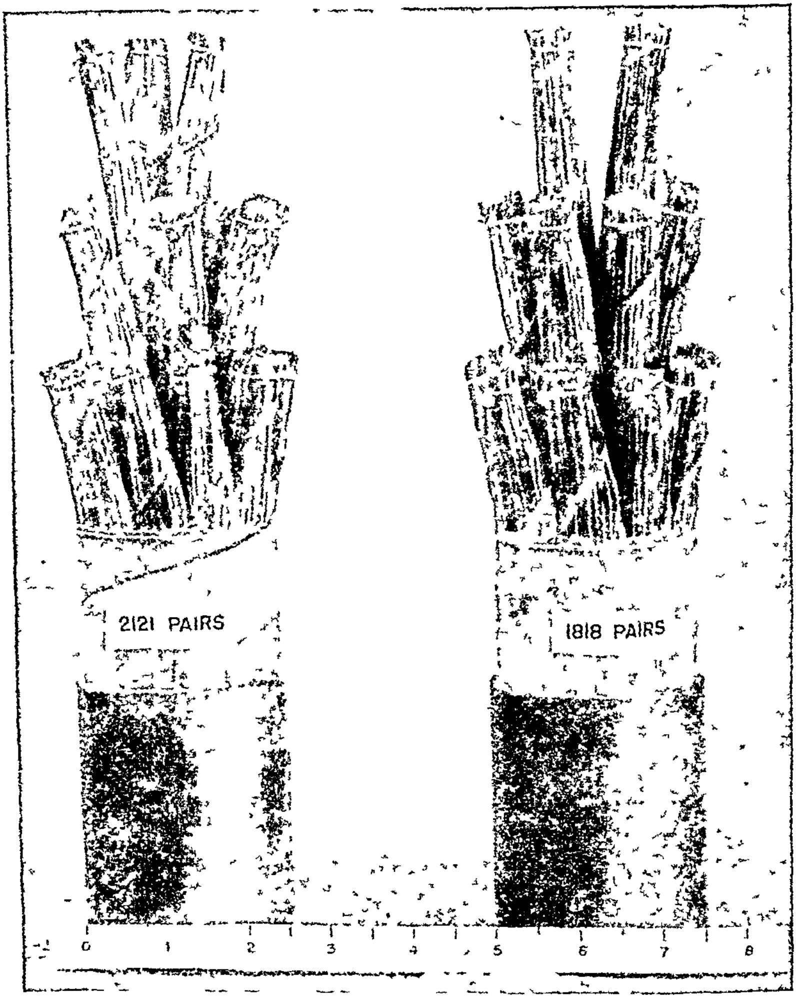
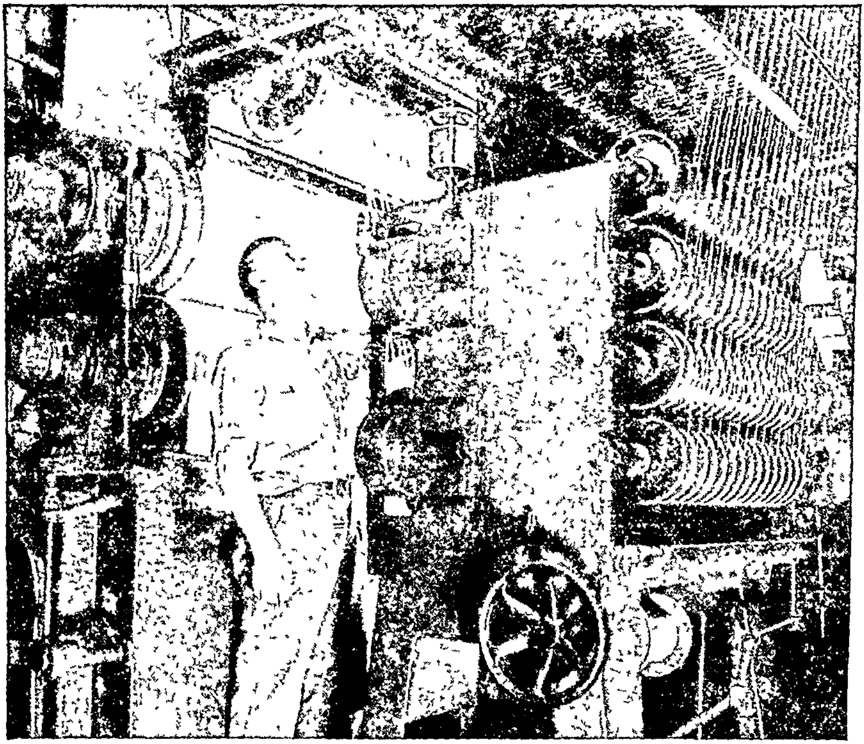


Fig 3 Section of largest telephone exchange cable in use is shown at left Improved technique of insulation has made it possible to enclose 2,121 pairs of wires within a cable no thicker—only 2⅝ inches—than the 1,818-pair cable on the right Seventy rows of poles, each holding aloft 60 wires, would be required to carry all the wires contained in this one cable

high-grade, open-wire toll lines threatened to check permanently the growth of the telephone system. In 1881, the engineers began to apply themselves to the special study of overhead and underground cables and the improvement of telephone lines. In 1882, experimental cables were laid for a short distance along a railroad track in Massachusetts.

Early in 1909, a sleet storm swept the Atlantic seaboard, paralyzing communication and isolating the capital at the time of President Taft's inauguration.[6] This caused the Bell engineers to intensify their efforts to make wire-burying possible, with the results that an underground telephone cable was completed in 1913 between Washington and Boston, a distance of 455 miles.



Courtesy, Western Electric Company

Fig 4. A partial view of the paper pulp insulating machine which played a large part in making it possible to put 4,242 wires in the space formerly occupied by 3,636 Starting with bare copper strands and pulp, the machine manufactures a thin coating of paper directly on the wire. Result: 3/1,000 of an inch saved in the thickness of each, totaling enough to make room for 606 more wires in a cable of the same girth

In certain localities where the requirements for underground cables are not sufficient to justify conduits and the conditions are otherwise suitable, cables having adequate protective coverings, in addition to the lead sheath, are buried directly in the ground for either toll or exchange service. This is usually done by means of a special type of plow Since 1930, when buried cables first came into extensive use, over 800,-000 miles of wire in buried cables have been placed in service. A simi-

[6] See "From wires to cables," p. 777.

lar method is used for burying rubber-insulated paired wire, a specially designed type of which has been developed for use in rural service.

The cable sheath. Up to 1912, the sheaths of cables used in the Bell system contained about 3 per cent of tin alloyed with lead. As a result of laboratory experiments and field tests begun in 1907, a new alloy was adopted, consisting of about 1 per cent of antimony alloyed with lead. This proved fully as satisfactory as the lead-tin alloy and was less expensive.

Cable development illustrates concretely the value of the research work carried on by Bell-system engineers. In 1888, the standard cable was capable of accommodating only 50 pairs of wires and cost between $150 and $160 per pair-mile to install, including the cost of ducts. Through constant experimentation, means have recently been found of increasing the number of wires so that a cable 2⅝ inches in diameter containing 2,121 pairs of Number 26 gauge wire is being manufactured. As contrasted with the 50-pair cable of 1888, the cost of this latest cable installed is in the order of $10 per pair-mile.

Radio telephony. Thorough research and extended experience demonstrate that the field of the wireless telephone is in maintaining communication between ship and shore, from ship to ship, or for talking from the ground to moving aircraft, or from airplane to airplane, or as an extension of the wire system bridging strips of desert or bodies of water, where it is impracticable to employ wires.

Before the advent of the three-electrode vacuum tube, attempts to communicate by radio telephony were discouraging. In 1912, Bell-system engineers began development of the tube as a long-distance wire telephone amplifier, or repeater. So satisfactory were the results that work was immediately begun on much larger tubes, to be applied to radio telephony.

The first successful demonstration of radio telephony, employing vacuum tubes, took place in 1915, when speech was transmitted from Montauk Point, Long Island, to Wilmington, Delaware, a distance of 250 miles. Later in the year, messages from Montauk Point were received at Jekyl Island, off the Georgia coast, 900 miles away. Messages from New York, carried by land lines, were automatically relayed to the radio equipment at the Long Island station and received in Delaware and Georgia—the first experimental use of radio as a supplement to wire telephony.

Overseas telephone service. Experimental transoceanic telephony by radio was first achieved in October, 1915, when speech was carried by electric waves from the Arlington station, near Washington, D. C., across the Atlantic to the Eiffel Tower, Paris, and also across the American continent and the Pacific to Honolulu, in the Hawaiian Islands. The air-line distance from Arlington to Honolulu is nearly 5,000 miles.

While the First World War delayed development of overseas service, on January 14, 1923, the Bell system carried out a successful demonstration of one-way transoceanic radio telephony when a group of telephone officials in New York talked for two hours by wire and radio to a group

of scientists and engineers assembled in London for the test. On March 7, 1926, for the first time in the history of communications, groups of people both in America and England conversed together by wire and radio during a test of two-way transatlantic telephony.

The goal of this long experimentation was commercial service between America and England through the combined use of wire telephony and radio. On January 7, 1927, President W. S. Gifford of the American Telephone and Telegraph Company formally opened commercial service between New York and London.

The scope of the service was thereafter gradually extended on both sides of the Atlantic; the hours of service were lengthened and the charges reduced. The demand for the service increased to such an extent that it became necessary to supplement the original long-wave radio circuit, and several short-wave circuits were added.

In 1930, radio-telephone service was established for the first time between North America and South America. In the same year, service was extended to Australia by way of the transatlantic circuit and a radio circuit between Great Britain and Australia.

The following year important island groups in distant seas—Bermuda, Java, Sumatra, and the Canary Islands—were included in the widening horizon of American callers, and a new radio center near San Francisco began the conquest of the Pacific by adding Hawaii.

During 1932, two major sections of the African continent—Egypt and South Africa—were reached as well as Siam in Asia. Another new radio telephone center was constructed near Miami, Florida, to provide service with the Bahamas and countries bordering the Caribbean.

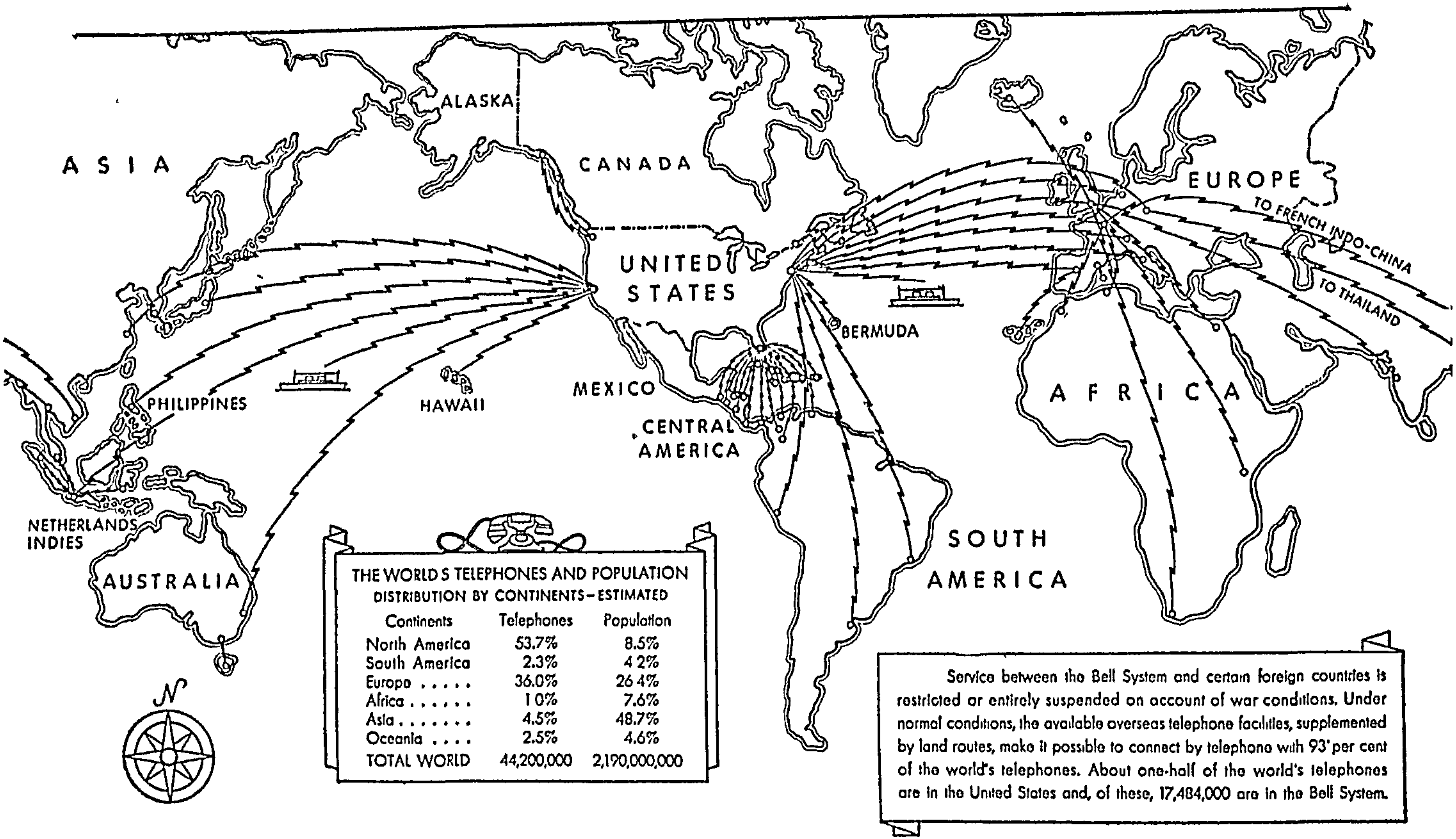
Among countries brought within the reach of American telephone users in the following years were the Canal Zone, the Philippines, Alaska, India, Japan, and China.

From any part of the United States, telephone connections can now be established with a total of 38,000,000 telephones, or about 93 per cent of all the telephones in service in the world.

During ship-to-shore radio experiments in 1920, two-way telephone communication was maintained for several months between several cities and two ships, the messages going by wire between these cities and the Bell system's experimental radio station at Deal Beach, New Jersey, and thence to the ships by radio.

In 1929, a regular service was instituted between shore telephones of the Bell system and the *S. S. Leviathan*, and today more than a score of large ocean liners have the facilities for regular telephone communication with the land.

In 1934, a ship-to-shore radio-telephone service was initiated for small boats operating in the vicinity of Boston, Massachusetts. Coastal and harbor radio-telephone service is now also available through radio-telephone shore stations at New York, Philadelphia, Norfolk, Miami, San Francisco, Los Angeles, Seattle, Lorain, Ohio, Lake Bluff, Ill., Port Washington, Wis., and Duluth, Minn. More than 1,000 boats have



THE WORLD S TELEPHONES AND POPULATION
DISTRIBUTION BY CONTINENTS – ESTIMATED

Continents	Telephones	Population
North America	53.7%	8.5%
South America	2.3%	4 2%
Europe	36.0%	26 4%
Africa	1 0%	7.6%
Asia	4.5%	48.7%
Oceania	2.5%	4.6%
TOTAL WORLD	44,200,000	2,190,000,000

Fig. 5 Overseas telephone connections of the Bell System.

installed radio telephones, and they can communicate through the shore stations with any Bell telephone.

The telephone central office. The telephones first placed in the hands of the public were leased in pairs. The lessee put up his own telephone wire to connect his telephone with that of a friend or neighbor, or ran the line between his home and his place of business At first, there was no way in which he could talk by telephone with the other individuals in the community who, like himself, had leased a pair of the early instruments.

It was the development of the telephone switchboard that made possible the interconnection of individuals and of communities, and thus broadened the telephone's usefulness to the public. What gives the telephone its great value today is the fact that it can be connected any time with any one of some 20,000,000 other telephones in the United States alone.

The switchboard and apparatus associated with it together comprise a central office. The lines, instruments, and other facilities by which the telephones of a community are given service are called collectively a "telephone exchange." In small communities, an exchange may include only one central office, while in larger communities it may contain many of these offices, in which case the community is known as a "multioffice exchange" Central offices are connected by telephone lines called "trunk lines." The lines that connect exchanges are called "toll lines."

A widely used method of making telephone connections utilizes switchboards operated by women who are called "operators." Because the work of establishing the connections and disconnections is done by hand, switchboards of this type are called "manual switchboards." When this work is done mechanically, the telephones are equipped with dials and the central offices serving such telephones are called "dial-system central offices."

Manual switchboards are divided into two kinds, depending upon the manner in which power is supplied for the talking circuits and the method of signaling the operator. In one type of switchboard, the power is supplied from a central plant that is located at the central office. These are called "common-battery switchboards" and the subscriber signals the operator by removing the receiver from the hook. In "magneto switchboards," on the other hand, the talking current is supplied by batteries installed on the subscriber's premises, and the subscriber signals the operator by turning a small crank on a magneto generator. Magneto switchboards are used only in some of the smaller communities. In the larger communities, both common battery manual and dial-system central-office equipment is used.

What the switchboard does. Three segregated pairs of telephones gives three talking lines. Unite three pairs of telephones by means of a central-office switchboard, and an intercommunicating system is formed which permits establisning 15 different communications where only three were possible before. An exchange system with 10,500 telephone lines gives 55,119,750 paths of communication. Putting it the other way

around, if it were physically possible to connect 10,500 telephones without a central-office switchboard, so that communication would be possible from each telephone to every other telephone in the group, it would require 55,119,750 talking circuits—that is, there would have to be 5,250 circuits multiplied 10,499 times.

Dial equipment Exhaustive investigation and experiments by Bell-system engineers and others over a long period of years resulted in the production of types of dial-operated central offices which meet satisfactorily even the most exacting service conditions. For some years, the Bell system has been gradually introducing the dial system where warranted by economic and service conditions. At the beginning of 1939, more than 8,250,000 Bell-owned telephones were operated from dial-system central offices—over 52 per cent of the total.

With the dial system the subscriber, after taking the receiver from the hook, instead of giving the number wanted to an operator at the switchboard, "dials" it by means of the dial at the telephone instrument. The dial central office is not operated entirely automatically but uses many operators for special purposes. Also, more men are required for maintenance of the equipment than in a manual office.

Dial service is more accurate than manual and somewhat faster; it also provides complete operating facilities for unusual volumes of business in times of emergency or in normally light traffic periods, when manual operating forces are on a skeleton basis.

Teletypewriter service. The teletypewriter is a means of transmitting written conversation just as the telephone is a means of transmitting vocal conversation. This form of communication service uses machines which, in many respects, are similar to typewriters. By means of key boards, electrical impulses are transmitted over a line, the character of these impulses being such as to cause the direct reproduction of messages in typed form on one or a number of similar machines that may be in offices across the street or across the continent.

There are two types of teletypewriter. One reproduces messages on standard-size pages, the other types on a narrow paper tape.

Teletypewriters are extensively used by the large press associations for transmitting much of their news traffic over Bell-system circuits. The rapidity of the service makes it especially useful in connection with stock-exchange report traffic. Brokers, too, are large users of teletypewriter service for the speedy transmission of short statements, requests for prices, and other market information between their offices.

The teletypewriter has proved of great value, also, in the administration and control of large business enterprises with plants, warehouses, branches, and offices at widely separated points. Orders, specifications, inquiries, reports, price changes, and other messages in which speed and accuracy are essential are rapidly transmitted by teletypewriter among the various branches of large steel, oil, manufacturing, and other companies.

The United States Department of Commerce uses more than 400 teletypewriters, located at more than 300 points—such as airports, weather-

reporting stations, and so forth—for the transmission of weather reports along the country's air routes. Commercial aviation companies are also users of the service, which effectively promotes safety in flying by furnishing departing aviators with up-to-the-minute information as to weather conditions that will be encountered. In many cases, the information thus transmitted to the airport is relayed to aviators in flight by radio telephone.

The teletypewriter is also rendering invaluable service to the police as a means of sending out alarms for escaping criminals, descriptions of missing persons and of stolen property, and the like. In these days when the automobile has facilitated quick escape, electrical communication is especially necessary for the interception of fugitives from justice Teletypewriter installations connecting police headquarters with outlying precincts or linking up the police stations of neighboring towns throughout a county or a state provide the means for sending alarms to all the connected points simultaneously and obviate calling each place in turn State-wide teletypewriter systems serve the police of many states. New York City, Boston, Chicago, Washington, and numerous other cities have also availed themselves of this means of combating crime. Many of these systems in adjacent states are interconnected, and all are coördinated with the various local police radio systems.

Teletypewriter centrals. The varied ways just mentioned of applying teletypewriters to the needs of business and Government repeat the early history of voice communication, since they involve the private use of wires for connecting fixed points, as was the case with the early telephones. The introduction of the first commercial telephone switchboard in 1878 opened up the possibility of an interconnecting service. A similar stage in teletypewriter usage was reached in 1931 through the development of a switchboard permitting the interconnection of teletypewriter circuits. This made possible the establishment of central offices and the institution of a general teletypewriter service whereby users can, upon request, be connected through the switchboard with other users for the interchange of typewritten messages, just as telephone service permits the interchange of the spoken word.

Pictures by wire. A method for the transmission of pictures over telephone lines developed by Bell engineers was first demonstrated in 1924. A successor to this system is now in daily use, permitting the transmission of photographs of important events coincident with news accounts.

The first public demonstration by wire and wireless of television, or "distant seeing," as developed by the technical staff of the Bell system, took place on April 7, 1927. Participating in the demonstration at Washington, D. C., and New York City were notable gatherings of leaders in the fields of science, industry, and public affairs. Those who talked from the Bell Laboratories in New York were able to see plainly the features of those in Washington with whom they conversed over the long-distance circuits of the Bell system. By means of a larger screen and loud speakers, all those present in New York were able to see the

speakers at the national capital and to hear the conversations over the wire.

This television demonstration between Washington, D. C., and New York over the telephone circuits of the Bell system was followed by a demonstration of television by radio between the Bell Laboratories in New York and an experimental station of the laboratories at Whippany, New Jersey. In 1929, television in color was demonstrated at the Bell Telephone Laboratories.

During the following year, two-way television was demonstrated over a wire circuit connecting the Bell Telephone Laboratories with the headquarters of the American Telephone and Telegraph Company.

By 1936, the developments in the Bell Laboratories of coaxial cable capable of transmitting more than 200 telephone conversations had progressed sufficiently so that an experimental installation between New York and Philadelphia could be undertaken to determine more completely the capabilities of this new system under actual field conditions. Late, in 1937, motion pictures were transmitted over this coaxial cable, which showed that its general characteristics were suited for television purposes.

This cable has now been equipped with repeaters at more frequency intervals and is being tested for a wider frequency band which will increase its telephone capacity to about 500 channels. Further experiments are being made looking forward to possible future demands for high-quality television circuits.

Economic Significance of the Telephone Industry

Much of the growth of American business over the past 50 years can be directly or indirectly attributed to the telephone. It stimulates buying and selling of commodities and service. Through it billions of dollars worth of business is transacted each day. Europe, South America, Australia, and Java are within calling distance of the United States; the isolated farm is brought in contact with the city markets. The telephone enters into every phase of private and business life. Our police and fire departments must have telephones, or the services they render would be drastically curtailed. The telephone brings the physician and the patient into speedy communication. The corner grocer delivers food to the housewife who has ordered by telephone. With our nation-wide telephone system ready for instant use, the alert and progressive business executive can sit in his office and control the operations of thousands of employees in different plants throughout the country.

Beneath the streets of our cities lie lead-sheathed telephone cables. The largest of these, not much larger than a man's wrist, contains 4,242 wires, constituting 2,121 circuits. Eighteen hundred persons connected to one end of such a cable can talk simultaneously with the same number connected to the other end without any confusion. Each of those 1,800 conversations is kept separate and cannot be overheard. There is no cross-talk from one circuit to another, though the insulation between is

but thin paper. Through such a cable with 1,800 individuals connected at either end, more than 1,600,000 conversational combinations are possible, but the traffic is so handled that wrong connections are relatively few. The stream of talk flows on, literally speaking, without let-up or hindrance through the city's hidden nervous system.

The telephone industry is comparable to our railroad and electric power industries from the standpoint of its fundamental importance in our present economic structure. It would be difficult to imagine the chaos which would descend upon us without warning if the telephone service were discontinued.

The telephone industry today. During 1939, the Bell system gained 775,000 telephones, as compared with 430,000 in 1938 and 876,000 in 1937. At the end of the year 1939, an all-time high of 16,536,000 Bell-system telephones in service was reached.

Also a new high record was the number of Bell-system telephone conversations in 1939, with local conversations well above, and toll and long-distance conversations slightly below, the previous high. The daily average number was 73,802,000, an increase of 3,906,000 over 1938. There were 5.6 per cent more local conversations and 5.5 per cent more toll and long-distance conversations than in 1938.

About 6,500 independently owned telephone companies and more than 40,000 rural lines in the United States have direct or indirect connecting arrangements with the Bell system and share with it the responsibility of furnishing nation-wide telephone service. Including the approximately 4,200,000 telephones of connecting telephone companies and rural lines, there were, at the end of 1939, about 20,750,000 telephones in the United States, practically any one of which can be connected promptly, not only with any other telephone, but with 93 per cent of the telephones in the world, except for those under restrictions in certain countries because of war. While the total number of telephones in the United States at the end of 1939 was the largest that it has ever been, the number of telephones per 100 population was 15.9, which is slightly lower than the previous high of 16.4 in 1930. Thus, the increase in the number of telephones over 1930 was a little less, proportionately, than the increase in population.

In 1939, the Bell-system gross operating revenue was $1,107,188,000, an increase of $54,530,000 over 1938, and the most in the history of the system. The total net income of the system applicable to American Telephone and Telegraph Company stock was $190,281,000, an increase of $34,738,000 over 1938.

Taxes continued to rise, and the total for 1939, including taxes charged to construction, amounted to $158,905,000, an increase of $11,474,000 over 1938, which year in turn showed an increase of $9,748,000 over 1937. Taxes in 1939 were equal to about 82 cents per month per telephone.

Forecasting the nation's telephone needs. When a new subscriber is provided with a telephone, there is given over to his use a share in the pole lines, underground cables and conduits, switchboards, exchange

buildings, and every other part of the complex mechanism of the telephone plant.

Obviously, this equipment could not be installed for each new connection. Practically everything but the telephone instrument must be in place at the time service is demanded.

This anticipation of the public's need involves a forecast by specialists among telephone engineers and statisticians that calls for intensive study and analytical skill in order to arrive at judgments that are of such far-reaching importance to the public. Increases in population in city and country must be calculated, and the growth of business districts must be determined, if a workable estimate of the number of possible telephone users and their approximate location is to be obtained.

The fields of sociology and economics, of geography and geology, of commerce and industry, are explored in this search for factors to be studied that may affect the growth of the community or district under consideration.

Where the coming generation will live and work is the concern of these engineers. Homes, shops, banks, theaters, factories, office buildings, and transportation systems yet to be built are in the forecast. Indications of growth and development in every department of civic expansion are traced and studied. Communities and other service areas, as they will exist two decades or more in the future, are what this forecast seeks to imagine, and upon this picture is imposed the most economical and efficient telephone system possible that will continue equal to the ever-growing needs of the people.

The construction, operation, and financial programs of the Bell system have their foundation on these scientific investigations. The necessity of foresight is evident when it is realized that, during the past year, 774,709 telephones have been added to the Bell system and that, during the same period, the Bell system has spent $214,289,622 on maintenance of its equipment to give the nation its needed service. As a measure of this demand in proportion to population, the system's extension in 5 years is equal to the total telephone progress of Europe since 1876, the year the telephone was invented.

A TELEPHONE CHRONOLOGY

1876 First telephone patent is issued to Alexander Graham Bell.
First complete sentence transmitted by telephone.
First two-way telephone transmission over an outdoor line, 2 miles, Boston to Cambridgeport.
1880 47,900 telephones in the United States, all Bell-owned.
1881 Conversation by overhead line, 45 miles—Boston to Providence.
Conversation by underground cable, ¼ mile.
1884 Conversation by overhead line (hard-drawn copper), 235 miles—Boston to New York.
1890 227,900 telephones, all Bell-owned.
1892 Conversation by overhead line, 900 miles—New York to Chicago.
1900 855,900 telephones owned by or connecting with Bell system.
1902 First conversation by long-distance underground cable—New York to Newark.
1906 Conversation by underground cable, 90 miles—New York to Philadelphia.

1910 5,883,000 telephones owned by or connecting with the Bell system.
1911 Conversation by overhead line, 2,100 miles—New York to Denver.
1913 Conversation by overhead line, 2,600 miles—New York to Salt Lake City.
Conversation by underground cable, 455 miles—Boston to Washington.
1915 First conversation by transcontinental line, 3,650 miles—Boston to San Francisco.
Speech transmitted for the first time by radio telephone from Arlington, Va., across the continent to San Francisco, to Hawaii, and across the Atlantic to Paris
1920 12,602,000 telephones owned by or connecting with Bell system.
1921 Conversation by deep-sea cable, 115 miles—Key West, Fla., to Havana, Cuba.
First conversation between Havana and Catalina Island by submarine cable, overhead and underground lines and radio telephone—distance 5,500 miles.
Extension of Boston-Philadelphia cable to Pittsburgh—total distance 621 miles.
1922 Ship-to-shore conversation by wire and wireless between Bell telephones in homes and offices and the *S. S. America* 400 miles at sea in the Atlantic.
1923 Successful demonstration of transoceanic radio telephony from a Bell telephone in New York City to a group of scientists and journalists in New Southgate, England.
First broadcasting of a presidential message to Congress
Completion of Southern transcontinental line.
1924 First public demonstration of picture transmission over telephone circuits—New York and Cleveland.
1925 New York-Chicago Telephone Cable completed—overhead—underground.
16,720,000 telephones interconnected in the United States.
1926 Successful test of two-way transatlantic radio telephony.
New York-Chicago, all-cable telephone line extended to St. Louis.
1927 Transoceanic telephone service inaugurated between New York and London.
Northern transcontinental telephone line formally opened.
First public demonstration of television by wire and radio.
Telephone service opened between the United States and Mexico.
1928 Transoceanic telephone service extended to principal countries of western Europe.
1929 Ship-to-shore telephone service established.
1930 Transoceanic telephone service opened to South America and Australia.
Two-way television demonstrated by Bell-system engineers.
20,098,000 telephones interconnected in the United States.
1931 Teletypewriter exchange service inaugurated.
Fourth telephone cable to Cuba opened.
Transoceanic service extended to Java, Sumatra, Bermuda, Hawaii, and the Canary Islands.
1932 Transoceanic service extended to South Africa, Egypt, Siam, and the Bahamas.
1933 A telephonic system for high-quality transmission and reproduction of orchestral music demonstrated by Bell-system engineers.
Transoceanic service extended to the Philippines, Canal Zone, and Central American countries, and to Palestine and India in Asia.
1934 Transoceanic service extended to Japan.
1935 First telephone conversation around the world.
1937 Transoceanic service extended to China, Bulgaria, Alaska, Haiti, and Iraq.
93% of world's telephones within reach of any Bell-system telephone.
1938 Direct radio telephone circuit established between San Francisco and Australia.

35

The Motion-Picture Industry[1]

Introduction

"Few people appreciate the commercial importance of the motion picture industry."[2] Few stop to ponder the enormous potency of this medium of entertainment which has become the universal recreation of the people. The screen is so taken for granted as a part of daily life that few realize how swift has been the progress of the motion picture from a mere visual novelty to a new and vital art, how spectacular has been the rise of the American motion-picture industry out of small, diverse beginnings to a series of great national and international undertakings in entertainment service.

In 1900, there was not a single movie theater in the United States. In 1910, vacant stores and warehouses were the only movie "palaces." The crudest melodrama flickered on the screen. No "stars" shone in electric lights, and the actors and actresses of these early film days were nameless to the audience. In 1921, the American motion-picture industry was a bedlam of disorganization from the public and industrial standpoints, with no possible industry program in sight.

In little more than a generation the motion picture has progressed from the peep show to the talking drama, traveled from the nickelodeon to the movie palace, and moved from the roof-top studio to the great studios of Hollywood. A world audience of more than 235,000,000 people has been created for the movies Chaos has given way to self-regulation in the industry Through coöperation and self-discipline, constantly higher standards of production are being evolved for the screen, and the whole world of literature, music, and entertainment is being encompassed in its service.

---

[1] This chapter was written in coöperation with Motion Picture Producers and Distributors of America, Incorporated Its authors wish to make particular acknowledgment to Terry Ramsaye, author of *A Million and One Nights;* to Professor H. T. Lewis (editor), "Cases on the Motion Picture Industry," in *Harvard Business Reports,* Vol. VIII, to *The Motion Picture Almanac* (New York: 1939); to *Film Daily Yearbook* (New York: 1940); and to *Film Facts, Incorporated* (New York: 1940).

[2] Lewis, *op. cit.,* p. 3.

Invention and History of the Motion Picture

The world owes the commercially practical motion picture to a happy coincidence of the inventive genius of Thomas A. Edison, who first contrived a marketable motion-picture camera, and of George Eastman, who perfected the flexible photographic film just at the time when Edison needed it.

Behind the work of these two men lay centuries of experiment in the fields of optics, mechanics, and chemistry. The scientific principles involved had been well-established. The phenomenon of the persistence of vision had been observed in the spinning coin, which reveals both its sides to the eye at once. It had been applied in a toy known as the "magic wheel," or "zoetrope," which whirled a series of painted figures into the appearance of a horse in motion. Photography had been discovered, and the magic lantern. It remained to synthesize these principles.

Contributions of Edison and Eastman. When Edison attacked the problem, several inventors had already taken groping and tantalizing steps toward a solution. The "Wizard" saw that a camera capable of taking photographs in rapid succession must be devised; some substitute for the cumbersome glass plates must be discovered. He tried a revolving cylinder; it worked, but not satisfactorily. This was in 1888. Edison realized that he must have some photographic material which could be fed into a camera, and subsequently into a viewing machine, on a belt. Someone told him about Eastman's new cellulose nitrate film; he tried it, and the problem was solved.

Early beginnings of the industry. The motion-picture business began in 1894, with the opening of the first peep show in New York. But the Edison kinetoscope, which could accommodate only one spectator at a time, did not satisfy the public. The motion picture needed the screen, and a secret race to invent a projection machine began. Several inventors succeeded simultaneously, a circumstance which kept the industry in patent litigation for many years. On April 23, 1896, the Armat Vitascope, manufactured by Edison, received its first public showing at the Koster and Bial Music Hall in New York Breaking waves, a bit of a prize fight, and a dancer flickered briefly on a sheet, and screen entertainment had been born.

The first motion-picture house—the nickelodeons. For several years, the vaudeville houses were the chief outlet for motion pictures. Then, in 1905, John P. Harris and Harry Davis, Pittsburgh real-estate operators, put a movie projector, a piano, and 99 seats into a vacant storeroom, advertised *The Great Train Robbery* (the screen's first story, made 2 years before), charged a nickel admission to the one-reel show—and packed them in! At once nickelodeons sprang up everywhere. Many of the men who were later to become leaders of the industry—Adolph Zukor, William Fox, Marcus Loew, Carl Laemmle—began with these store shows and the penny-arcade kinetoscopes. By 1907, there were

5,000 nickelodeons; the picture public was growing by the hour, and the producers were swamped with demands for film.

Pooling the motion-picture patents. In 1906, both the Biograph and Edison Companies, chief rivals in the patent wars, set up large studios to supplant their roof-top and backyard methods. In 1908, a truce was reached, and the Motion Picture Patents Company was formed to pool all patents and to license picture producers and exhibitors. For a brief period, the Patents Company held a strong position in the industry, but inertia put it out of business within a decade. Enterprising challengers sprang up; inspired by a vision of the screen as an important new dramatic art, and determined to lift the business from the narrow confines of the nickelodeon and its one-reel films. The "feature picture" arrived.

The feature picture established. Adolph Zukor was the chief exponent of the "big-picture" idea. He began by importing Sarah Bernhardt's *Queen Elizabeth* in 1912; 4 years later, he merged his own Famous Players Production Company with Lasky's, bought the Paramount distributing organization, and stepped into the leading position in the industry. This period saw the rise of stars like Mary Pickford, Charlie Chaplin, Mae Marsh, Norma Talmadge, and many other favorites. In 1914, the Strand Theatre opened on Broadway, the first large theater devoted to motion pictures. In 1915, D. W. Griffith's *Birth of a Nation* opened for a long run on Broadway and a nation-wide popularity which was to endure for years. The new art of the feature picture was established, and the nickelodeon was rapidly on the way to extinction.

Organizing the motion-picture industry. A new integration of the industry—horizontal mergers of producers, distribution exchanges, and theaters, and vertical consolidations of all three groups—went on apace. In 1922, a new step to stability was taken through the organization of the Motion Picture Producers and Distributors of America, Incorporated, headed by Will H. Hays, Postmaster General in the cabinet of President Harding. Year by year, the industry grew in technical proficiency and in appeal to increasingly large audiences. The pattern of showmanship and the problems of the business seemed to be fairly well-established and understood.

Advent of sound picture. Then came sound, and the whole industry was again revolutionized. New production methods, both technical and artistic, had to be evolved; new studios had to be built and theaters had to be wired with sound equipment; every uncertainty of an expensive innovation confronted the industry. The industry took all this in its stride. The result justified the thoroughness of the industry's decision. Dialogue brought to the theaters millions of new patrons.

The advent of sound in the motion-picture theater came in 1926, but the change-over from silent pictures could not get fully under way until about 2 years later. Warner Brothers was first in the field, with other companies close behind. Synchronization of sound and motion pictures was not new, even then, but for the first time it was successful. Edison had combined his kinetoscope and phonograph as far back as 1894. Satisfactory amplification of the voice remained an unsolved difficulty,

however, until about 1921 [illegible] pictures the principles [illegible] tories [illegible].

The principle of sound pictures. [illegible] systems [illegible] electrical impulses [illegible] in the vibrations [illegible] in the sound vibrations [illegible] the picture [illegible] the sound is reproduced in synchronism with the motion on the screen.

The Social Significance of Motion Pictures

The motion picture [illegible] It emerged from the [illegible] the curious few might be entertained by [illegible] quaint moving images. It rapidly developed [illegible] medium which [illegible].

By 1922, a growing consciousness of the social importance of the motion picture found expression through the Motion Picture Producers and Distributors of America.

Self-regulation established by the industry. The main steps of self-regulation established by the motion-picture industry since 1922, under the leadership of Mr. Hays, may be briefly summarized as follows:

First came the general policy of public coöperation, which crystallized with the formation, in 1922, of a committee composed of leading public welfare, social, religious, and educational groups in the United States. This was the first conduit built to convey to the industry the standards of public taste as interpreted by responsible leaders of public opinion.

The coöperation thus achieved developed later into the "open-door policy," through which the fullest expression of opinion was invited as to the betterment of motion pictures. Today, organizations representative of at least 6,500,000 people in the United States are coöperating in a constructive movement for better pictures.

In 1924, a formula was adopted by the organized motion-picture industry to avoid the picturization of books and plays that could only be produced in such form as to leave the producers subject to a charge of deception or that might attract unsuitable material to the screen. The principles of this formula were embodied in 1927 in an agreement between the Motion Picture Producers and Distributors of America, Incorporated, and the various guilds of authors and dramatists.

In 1927, the fourth great step was taken. A Studio Relations Committee was established with headquarters in Hollywood. This committee is the sieve through which the ideas, suggestions, and criticism of public groups are passed on directly to the production executives of the industry.

Motion Picture Production Code. During all this time, production standards were being established in the form of resolutions adopted by the organized industry, through the Motion Picture Producers and Distributors of America. From these came the first production code. Later, with the addition of sound to the motion-picture screen, it was found necessary to add new standards and restate the principles that governed the production of motion-picture entertainment. This resulted in the present Motion Picture Production Code, announced by the industry in March, 1930.

Policies of motion-picture producers. The code, which has been subscribed to by all the leading people in the industry, sets up both general principles and specific applications governing the pictures to be made by any member of the Motion Picture Producers and Distributors of America. The principles laid down in the code follow:

(1) No picture shall be produced which will lower the moral standards of those who see it. Hence the sympathy of the audience should never be thrown to the side of crime, wrongdoing, evil, or sin.

(2) Correct standards of life, subject only to the requirements of drama and entertainment, shall be presented.

(3) Law, natural or human, shall not be ridiculed; nor shall sympathy be created for its violation.

The code, a voluntary agreement entered into by the member companies, is administered by the association through the Production Code Administration. Code machinery is available to all producers, foreign or domestic, whether or not they are members of the association.

Similar standards have been set up for advertising by a separate code. The development of constantly higher standards of production in the motion-picture industry is, from the social standpoint, obviously a vast educational process. The success of the system can be measured, not by perfection, but by progress.

Marked social progress of the screen. The very marked social progress of the screen is made evident by the reports published by previewing bodies, representing large public groups engaged in the work of classifying films from the standpoints of adult, family, and child entertainment. Representatives of such national organizations as the General Federation of Women's Clubs, Daughters of the American Revolution, International Federation of Catholic Alumnae, Young Men's Christian Association, American Library Association, Boy Scouts of America, and similar bodies inspect motion pictures in advance of release and report their recommendations to their membership.

Economic Significance of the Motion Picture

Motion-picture entertainment has taken its place with the major essentials in the economic world. With motion and sound and color at its command, the screen is able to bring to a vast popular market every service of entertainment, information, and education.

The motion-picture industry operates under a unique system whereby every product it releases may be merchandised from the highest to the lowest possible popular price range. Even in the crisis of war, movie entertainment has been defined as an essential service. No other form of entertainment offers such a wide variety universally distributed and at a price within reach of every stratum of the population.

As in other industries where research and market development are legitimate costs of the business, entertainment research and development are constantly in progress in the motion-picture industry. Taking the fact into consideration that the motion picture is an artistic as well as industrial product, the larger part of the expenditures involved in experimenting with literary, dramatic, and other material is properly chargeable to enterprise.

When valuable machinery is scrapped to make way for newer and better processes, when vast research laboratories "waste" millions of dollars each year in investigation and discovery, when new lines of merchandise are manufactured to tap possible new markets, when every successful newspaper must buy twice as much material as it uses, when vastly more misses than hits issue from the publishing industry, the investment chargeable to enterprise is an accepted factor of business. But when a story bought for picturization is shelved because of production problems subsequently developed, when investments in entertainment personalities are made subject to the confirmation of public favor, or when a finished film is refashioned in the attempt to make it better, the cost often seems "waste" to the uninitiated.

The motion-picture industry, like other industries, has important problems of management, and cost and control systems are constantly being perfected in every department of studio operations.

Influence of the industry on other industries. The moving picture is a universal stimulus to all forms of American business. Its direct contributions are easily visualized. Translated into terms of family life: 300,000 of our people buy their necessities and luxuries alike with money earned in the production, distribution, and exhibition of motion pictures. The industry spends $57,000,000 each year in the one field of newspaper advertising. The building industry, the electrical-supply trade, transportation, printing, heating equipment, fuel—these and many other fields depend for a considerable portion of their prosperity on the continued growth and stability of the motion-picture industry.

Its indirect contribution to the world of business staggers the imagination. The clothing of the farm boy cannot be distinguished from that worn by the city boy. Using the movies as a criterion of up-to-date wearing apparel, people fashion their clothes, in modification, after those seen on the screen. The farmer's home and the city man's home show the effect of motion pictures, for everything that is useful and beautiful for the home is pictured on the screen, which creates the desire for possession.

The motion picture, in fact, is not only a national but an international salesman. It brings America and its products to Singapore and China.

It has been said facetiously that the American motion picture has taken the fez off the Turk and put the derby on him instead, that it has cut off the Chinaman's queue and parted his hair in the middle. It has made the bathtub a solace rather than a menace throughout the world.

On the other hand, American films bring the whole world to our own doors.

The Industry Today

Today, the business of supplying motion-picture entertainment ranks among the leading industries of the United States. Its invested capital is estimated at $2,050,000,000. Every year it consumes 2,000,000,000 feet of photographic film.

Leading companies in the industry are associated in the Motion Picture Producers and Distributors of America and in the allied Association of Motion Picture Producers in California.

Production

Geographical locations of production—distribution centers. The twin capitols of the American movie kingdom are Hollywood and New York—Hollywood, the studio center, where virtually all American films are made; New York, the seat of distribution and financing. There are good reasons, which counterbalance the obvious disadvantages, for this geographical concentration of picturemaking 3,000 miles away from the home offices of the companies. Chief of these is climate and scenery. The motion-picture pioneers who first ventured out to California found there everything a film director could ask. They found plenty of sunshine and little rain, and a great variety of natural settings within a short radius—mountains, seas, deserts, ruins, city streets, and even, crossing over into Mexico, the jungle. These advantages brought most of the studios to Hollywood and established that city as the production center of the industry. The coming of sound, bringing an increased use of indoor "shooting," has lessened the importance of the climatic and scenic factors; but because of the large investments in real estate and equipment and the concentration there of the motion-picture actors' colony, it is likely that Hollywood will maintain its supremacy for a long time to come.

First steps in production. The first step in making a motion picture is the selection of a story; the next, the preparation of a budget. In these two steps is emphasized the fact that the making of film plays is not only an art but a business—a highly competitive business which uses extremely expensive raw materials. A definite cost figure for every picture is allotted in advance. The fact that the budget is occasionally exceeded perhaps emphasizes the fact that making pictures is not only a business but an art.

Who makes the movies. Each studio in Hollywood is a small town. It has its office buildings, its theater and projection rooms, its streets,

and its industries, ranging from carpenter, paint, and blacksmith shops to electrical plants and dressmaking establishments.

Housed within the gates of each studio are between 2,000 and 3,000 workers—artists, writers, stenographers, architects, carpenters, painters, electricians, cameramen, laboratory workers, and sound men, to mention but a few of the 276 trades and professions represented. The actors themselves are only a small part of a studio's population.

Each studio has its own individuality. Those situated in congested districts are compactly built to utilize every inch of space. Those occupying sites in the suburban sections give a feeling of spaciousness. The studios usually have "ranches" somewhere in the San Fernando Valley, where many of the large outdoor sets are built and where these scenes are shot.

The production of a talking picture is one of the most complicated jobs in the world. Between an author and his novel stands nothing but his pen, between a painter and his canvas nothing but his brush; but between the conception of a motion picture and the finished production stand many minds and arts. First, there must be a story. The literature of the world crosses a producer's desk. Every important novel is read by the story department long before it goes on popular sale. The magazines provide a vast field of material. Trained scenarists are busy on originals. Once the story is selected, difficulties begin. One must fit the cast to the story or the story must be fitted to the cast. From beginning to end in writing a scenario, the research department checks every detail. The property department studies the script as it grows and begins to gather the required props. Everything must be ready, down to the last ash tray on a desk. Then there is the business of costuming a picture. Architects, carpenters, and painters go to work on the necessary sets.

Eventually the stage is set and cameras go into action. Sometimes a start is made in the middle of the script and at other times the last scenes are shot first. Sometimes the entire cast must go on location. There is the job of sound recording, the scoring of music for the pictures, and finally the editing of the film. Every stage of production must be under expert supervision. Mistakes are costly.

The producer is the guiding force in the making of a talking picture; he is charged with responsibility for the starting and finishing dates, for budgeting items, for the selection of story material, and for the cast and director. The director's responsibility is to consolidate and to obtain a smooth dramatization of the story; he is to the picture what a conductor is to an orchestra.

It is estimated that the average production record in the larger Hollywood studios is 3 minutes of finished film in an 8-hour day. In shooting difficult scenes, it will average considerably less. Few pictures are made in less than 30 days, and sometimes it takes a year.

The next time you watch a picture consider, for a moment, the time and care taken in perfecting the brief scene flitting before your eyes. Weeks and possibly months of preparation have preceded this minute on

the screen. Art directors, set directors, heads of wardrobe and property departments, librarians, sound engineers, cameramen, directors, and producers—all have contributed their efforts and talent, along with the actors who march across the stage.

Visitors to Hollywood are always amazed at the amount of effort required to film even the simplest scene, yet there is a minimum of waste in the studios today. It is arranging for the thousands of technical things which keep a picture moving and maintain suspense at a high point that takes up the time. Motion pictures have never been made more skillfully or more efficiently than they are today.

TABLE I

THE PRODUCTION DOLLAR

Costs	*Per Cent*
Cast	25.0%
Extras, bits, and characters	5 0
Director	10.0
Director assistants	2.0
Cameraman and crew	1.5
Lights	2 0
Make-up, hairdressers, and supplies	.9
Teachers	.2
Crew and labor	1 2
Story preparation	7.0
Story costs	5.0
Costumes and designers	2.0
Sets and art directors	12.5
Stills and photographs	.4
Cutters	1 0
Film negative	1.0
Tests	1.2
Insurance	2 0
Sound—engineering and negatives	3.1
Publicity, transportation, research, technical, and miscellaneous	2 0
Indirect costs	15.0
	100.0%

Self-regulation. All through the writing of the scenario, the shooting of the picture, and the final editing of the film, members of the Production Code Administration—the industry's self-regulatory organization—actively coöperate with the writing and production units to see that the standards of good taste as laid down by the production code, voluntarily adopted by the industry, are maintained.

Production personnel. In the 20 larger studios, there are approximately 150 contract stars and about 400 feature players. In addition, there are 40 or more better-known stars and feature players who work on a free-lance basis, moving from studio to studio. There are 246 active directors in the motion-picture colony, 400 assistant directors, and approximately 700 film writers. There are 650 trained motion-picture cameramen. In the music field, composers, lyricists, and supervisors

make up a group of 210. Available for the musical pictures are from 37 to 40 experienced dance directors.

Activities of the central casting bureau. Among the examples of industry coöperation through the association is the Central Casting Bureau at Hollywood for "extras," the supernumeraries or small-part actors who are engaged from day to day as the demands of scenarios may require. This bureau helps the studios by its efficient service and is also a boon to the players because it operates without cost to them.

In the past 10 years, the average number of placements of extras has run from 800 to nearly 1,000 a day, with total annual wages running from $2,500,000 to $3,125,000. The total number of individuals used in the course of a year ranges just below 10,000. Of these, between 6,000 and 7,000 earned less than $500 for the year, and the fortunate few in greatest demand—some 60 individuals—earned between $2,000 and $3,000.

Distribution

The sale[3] and physical distribution of motion pictures is handled by the sales department of each company or, in a few cases, by a separate organization which has contracted with the producer to distribute his pictures.

Most sales of motion pictures formerly were made by seasonal contracts signed in advance. Under the system of "block booking"—that is, the licensing of a group of films wholesale—the exhibitor could contract in one block for all or a large part of a given producer's film output.

Sales practices have been changed, however, by a consent decree signed by five major motion-picture companies[4] and approved on November 20, 1940, by Federal Judge Henry W. Goddard (U.S.D.C.S.D N.Y.-Eq. No. 87–273). Under the terms of the decree, which went into effect on September 1, 1941, the consenting companies agreed to limit wholesale selling to blocks of not more than five pictures. Trade showings of pictures must be held in each distribution territory so that exhibitors may have an opportunity to see them before licensing.

Exhibition. Recent surveys place the number of motion-picture theaters now operating in the United States at approximately 17,000. The total seating capacity of American movie houses is set at 11,000,000, and the attendance is estimated at 85,000,000 admissions a week.

The various types of motion-picture houses and their programs are no doubt familiar to everyone. There are the huge de luxe theaters in the downtown shopping and theatrical districts, presenting first-run feature pictures. In the residential districts are the "neighborhood" houses The very large theaters change their programs once a week, or less frequently if the feature is sufficiently popular to hold over. The smaller

[3] Strictly speaking, films are not sold to theaters. The distributor merely grants a license to the exhibitor to show a picture at a specified place and time, and lends him the necessary positive print.

[4] Paramount, RKO, Loew's, Warner Bros., and Twentieth Century-Fox.

houses have two, three, or even more changes of program weekly, depending upon their patronage, and many show double features.

To keep his theater supplied with entertainment that will bring the public to his box office is the chief concern of the exhibitor. It was customary for him to contract in advance, purchasing according to his best judgment from the offerings of the competing companies, for enough pictures to fill an entire year's playing dates. The changed methods by which he now buys his films have been outlined in the section on distribution. Advertising and exploitation of his programs (with the assistance of material supplied by the distributor) is another important function of the exhibitor. All details of theater management are also in his hands.

Foreign distribution. American motion pictures long ago became an international entertainment. Even today, in spite of the language difficulties brought about by talking pictures and the stringent regulations imposed by several foreign countries in an effort to encourage native studios, Hollywood produces the majority of films shown in nearly every country in the world. The extent of foreign distribution differs with each company, but it is estimated that 35 per cent of the rentals of feature films come from the foreign market in normal times. The langauge difficulty is met by the making of translated versions in foreign tongues.

Financing

The financial structure of the motion-picture industry today is no different from that of any other established and stable business. The companies are capitalized through issuance of common and preferred stocks, listed on the stock exchanges, and additional financing is provided by the usual means of bonds, notes, debentures, mortgages, and so forth.

Trade Practices of the Motion-Picture Industry

Side by side with the mechanical and artistic progress of the screen, a system of trade practices, of absorbing interest to the student, has grown up in the motion-picture industry. Like the theatrical producer who "puts on" a play or the concert impresario who stages a concert, the motion-picture producer, although his product is on a film, is engaged in the business of entertainment service. The return on his investment and his enterprise must come from the relative success or failure of the entertainment production he rents out. Films are licensed, not sold, to the individual exhibitor.

Factors that determine the rental of a film. The exhibitor buys the right to exhibit the entertainment feature created by the producer. Unlike the producer who sells a commodity or a manufacturer who markets a product, the motion-picture producer cannot place a uniform price upon the entertainment service he offers. The price in each case must be determined by the character and extent of the box-office draw. Thus the film for which a Broadway movie house pays many thousands of dollars

in rental may bring only $10 in a small country town. What a given exhibitor should, can, and does pay for any given film or group of films depends upon the location of his theater, the seating capacity, the probable drawing power of the pictures in his community, the time that has elapsed since the picture had been shown in other communities, and other factors—all of which the salesman and the exhibitor cast into the balance as they negotiate their bargain. Under this system, every film, no matter how costly or successful, eventually reaches the remotest village and hamlet.

Percentage system. Of recent years, the percentage system of film rental, by which the distributor receives a specified share of whatever receipts the picture draws into the theater, has come into increased use, particularly at the more important houses. Sometimes a combination of a guarantee and percentage is the basis of sale. In the smaller theaters, the flat-rental system generally prevails.

Theory of film rental. All these systems are based on the general principle that the theater should pay for the rent of a film a fair share of the revenue that film will bring to its box office.

Special feature films. It is common practice among the large companies to produce annually a certain number of exceptional pictures known as "specials," as distinguished from the "program" features which make up the bulk of the output. These "specials" have long runs on Broadway and in key theaters elsewhere and are then sold generally on terms based upon their demonstrated popularity.

Receipts and selling expense of films. It is estimated that the large theaters in cities account for about 75 per cent of the total gross domestic receipts of each film. The remaining 25 per cent of the revenue, essential to profitable operation, is obtained at a much higher selling expense. Sales to the large chain operators are usually made through the home distribution office, while the individual theaters must be visited by salesmen working from the regional branch offices of "exchanges."

Newness and price of films. From the very beginning of the motion-picture industry, newness has been the dominant factor in determining the price of a picture. A "first-run" house pays a premium for the right to show a film first in its territory; the "second-run" theater pays a lower price; and so on down the line to the 10-cent show, which must be content with films that are several months old. Booking the positive prints of a picture to theaters in the order of their precedence and the physical shipment of the film is the work of the branch exchanges. Usually about 250 positives of a film are in circulation in the United States and Canada, but this figure may vary from 150 to 400.

The revenue-bearing life of a motion picture is usually less than 2 years, except for foreign sales and trifling domestic rentals. One large company's experience has been that 86 5 per cent of a picture's earnings are taken in the first year.

Increase in educational activities. The Motion Picture Producers and Distributors of America has not confined its activities to the business problems of its industry or the responsibility of furnishing proper enter-

tainment to the public. Throughout the years of its existence, it has been constantly at work to make the motion picture of greater educational usefulness, in classrooms, in churches, and in hospitals. The members of the association are coöperating with educators in three distinct programs, as follows.

Photoplay appreciation groups. By supplying study guides, research exhibits, and other materials supplemental to the photoplays based on classics of literature or classics in their own right, the industry has encouraged the serious study of the motion picture as an art form and as a medium through which new interest can be brought to the study of literature, history, and the social sciences. Leading educational organizations, as well as individual high schools, colleges, and universities, are coöperating. There are 6,000 high-school courses in motion-picture appreciation. Mailing lists are maintained by the M. P. P. D. A. for the materials prepared by educators and made available without cost through the courtesy of individual producers as their pictures lend themselves to study.

Films on human relations. As early as 1929, a group of educators, finding text materials poorly adapted to the teaching of human relations —"character education"—asked the M. P. P. D. A. to undertake the production of a series of pictures designed for this purpose.

In the intervening years, much had to be learned before the Commission on Human Relations of the Progressive Education Association, assisted by the Rockefeller Foundation and the M. P. P. D. A., could present its present library of 61 subjects dealing with the important problems in human relations that confront American youth in and out of school.

These films are available at small rentals for use in schools only where approval of personnel responsible for their presentation and subsequent discussion is given by the Commission Director, Dr. Alice V. Keliher.

Teaching Film Custodians, Incorporated. The conflict between exhibitor objection to and teacher insistence on the use by schools of no longer current theatrical short subjects was resolved in 1937, when the M. P. P. D. A., with the educational supervision of a distinguished Advisory Committee on the Use of Motion Pictures in Education, explored the vaults of its members and found there, through review by teacher panels, some 1,000 one- and two-reel subjects worthy to be shown and wanted in American classrooms. By 1939, 500 of these films were catalogued and entrusted to Teaching Film Custodians, Incorporated, for release direct to schools deserving them. The films are available on a 1-, 2-, or 3-year basis at low, nonprofit costs.

In these and other directions, the motion-picture industry is experimenting to find new spheres of usefulness to society.

TABLE II

STATISTICAL HIGH LIGHTS OF THE MOTION-PICTURE INDUSTRY

Approximate weekly attendance for 1939:		
United States		85,000,000
Rest of world		150,000,000
Estimated gross box-office receipts in U. S. motion-picture theaters for 1939		$1,000,000,000
Estimated taxes paid to Federal Government annually		$100,000,000
Estimated taxes paid to state and local governments annually		$250,000,000
Feature pictures approved in 1939 by Production Code Administration:		
New features:		
Domestic	519	
Foreign:		
Member companies	8	
Nonmember companies	57	
	584	
Features re-issued:		
Domestic	11	
Foreign	1	
	12	
Total		596
Estimated capital investment in the United States motion-picture industry:		
Theaters	$1,900,000,000	
Studios	125,000,000	
Distribution	25,000,000	
Total		$2,050,000,000
Estimated number regularly employed in the industry:		
Exhibition	245,500	
Production	29,500	
Distribution	12,500	
Total		287,500
Approximate annual payrolls:		
Exhibition	$250,500,000	
Production	92,000,000	
Distribution	27,560,000	
Total		$370,060,000
Major studios:		
West	20	
East	2	
Total		22
Active producing companies		92
Number of distribution zones used		31
Number of branch offices (film exchanges) maintained in U. S. for wholesale distribution		447
Estimated number of film shipments per year between film exchanges and theaters		15,000,000
Average number of positive prints required for each feature picture		250
Average number of bookings per print		37
Average number of actual playing days per print		100
Average cost for each positive release print (feature length)		$200

Approximate amount of linear feet of positive film used annually		2,000,000,000
Total cost (at 1¢ per foot)		$20,000,000
Approximate amount of linear feet of negative raw stock used annually		100,000,000
Total cost (at 4¢ per foot)		$4,000,000
Number of theaters showing a feature picture distributed nationally		2,000-12,000
Approximate number of first-run theaters in 95 cities of over 100,000 population		450
Number of different industries, arts, and professions involved in the making of a U. S. feature picture		276
Total motion-picture theaters in U. S. equipped for operation, as of		
1936:		
In operation	15,378	
Closed	3,130	
Total		18,508
1937:		
In operation	16,258	
Closed	2,560	
Total		18,818
1938:		
In operation	16,251	
Closed	1,290	
Total		17,541
Average seating capacity (all theaters)		623
Estimated average admission		$.23
Number of towns with motion-picture theaters equipped for operation		9,187
Total number of theaters equipped for operation		17,541
Total seating capacity of theaters equipped for operation		10,924,484

TABLE III

APPROXIMATE DISTRIBUTION OF UNITED STATES BOX-OFFICE RECEIPTS FOR 1938

Estimated gross box-office receipts for all U. S. motion-picture theaters for 1938		$1,000,000,000
Theater retains 65% of total receipts for local expenses, as follows:		
25% Payroll, theater staff, and management	$250,000,000	
15% Real estate—Rent, insurance, taxes, interest, and depreciation	150,000,000	
8% Local advertising and publicity	80,000,000	
5% Light and heat	50,000,000	
5% Interest and dividends	50,000,000	
4% Other taxes and insurance	40,000,000	
3% Miscellaneous extra attractions (acts, music, prizes, contests, etc.)	30,000,000	
Total		$650,000,000
Theater pays 35% of total receipts for film rental, as follows:		
25% To studios for producing the film	$250,000,000	
10% To wholesale distributor for prints, advertising, sales, and service costs, *etc.*	100,000,000	
Total		$350,000,000

36

The Radio Industry

Early Discovery of Radio Waves

Wireless wave foretold—James Clerk Maxwell. Of all the wonders that radio has brought to man and of all the new miracles that it promises for the future, perhaps the greatest single curiosity of this art is that it was not "discovered" but actually foretold by means of pure, mathematical speculation years before its attainment.

In 1873, man's knowledge of the basic laws of electricity was very limited The full scope of application of this invisible force was not even dreamed of. Yet, in that year, James Clerk Maxwell, a Scotch mathematician, published a treatise entitled *Electricity and Magnetism,* in which he demonstrated, purely by mathematical reasoning, that rapidly oscillating electrical currents would give rise to an electromagnetic disturbance, or "electric wave," which would travel away from its source of origin. Maxwell even foretold the velocity of this "wireless wave," stating that it would have the same speed as light.

First demonstration of electromagnetic waves—Heinrich Rudolph Hertz. This amazing prediction stirred scientific men the world over to intensive researches in high-frequency phenomena, but it was not until 1887 that Dr. Heinrich Rudolph Hertz, an eminent German scientist, demonstrated for the first time the actual existence of such electromagnetic waves. Hertz not only produced wireless waves but measured their length and velocity as well; what is more, he showed that they followed the ordinary laws of light with regard to interference, refraction, and polarization. Hertz succeeded in propagating these waves over a distance of a few feet, but these experiments, beyond demonstrating the possibility that such waves might one day be "harnessed" in the interest of space communication, accomplished nothing of a practical nature.

Other pioneers in radio. In 1892, Professor Edouard Branley, a French scientist, noted that metallic filings placed in a glass tube between two brass lugs would cling together, or "cohere," in the presence of electromagnetic waves. This same phenomenon has been observed by S. A. Varley in 1866 and by Professor A. L. Hughes in 1879. In later years, this wave detector acquired the name "coherer." In 1894, Sir Oliver Lodge, a noted English professor and scientist, repeated, with

improved apparatus, some of the experiments of Hertz and other pioneers in this field. Professor Popoff, a Russian scientist, also performed experiments with this metallic filings detector and had observed its responsiveness to electrical disturbances created by approaching storms.

First practical radio communication—Marconi. Important as was the work of these early pioneers in the radio art, it remained for Guglielmo Marconi, a young Italian, to combine the results of their work in research of his own, and in 1896, he demonstrated how these various inventions could be coördinated for practical results. To Marconi must go the credit for establishing the first method of communication by radio to be recognized as practical beyond a scientific doubt. In coördinating the earlier work of other experimenters, he used some of the elements of the Hertz spark transmitter and added thereto an aerial wire and ground plate. He also attached an elevated aerial wire and ground plate to the coherer at the receiving station. Thus he developed a transmitting system that radiated more powerful waves and a receiving apparatus more sensitive to these waves than the apparatus of any of his predecessors. Sir Oliver Lodge introduced some improvements on the Marconi system in 1897, by which tuning, or synchronization, of the transmitter and receiver to a fixed wave length could be more readily attained; and from 1899 on, Marconi himself evolved new methods which made it possible to transmit signals through space over considerable distances. Indeed, by 1901, Marconi was able to receive telegraph signals at a wireless station located at St. Johns, Newfoundland, from a station at Poldhu, in Cornwall, England—a distance of about 1,800 miles. By 1902, messages were transmitted from shore to ships, in some instances over distances of 2,000 miles.

United States Genius Enters the Picture

Initial interest in this new art in the United States began with Marconi's demonstrations before the officials of the United States Government in 1899, when Marconi wireless equipment was installed in the battleship *Massachusetts*, the cruiser *New York*, and the torpedo boat *Porter*. The United States Naval Board made a favorable report on the usefulness of the Marconi system, even though the range of communication was limited by factors which have long since been overcome. The Marconi Wireless Telegraph Company of America was organized in that same year.

Early American contributors to the field of radio. As the result of the publicity accompanying the early Marconi demonstrations, American genius, beginning in 1901, applied itself to further improvements of the art. Individual research physicists throughout the world began an intensive study of electrical-wave phenomena. Among the numerous early United States experimenters were Dr. Lee DeForest, Professor Reginald Fessenden, Walter Massie, Harry Shoemaker, John Stone Stone, and G. W. Pickard.

Dr. Lee DeForest. In 1901, Dr. Lee DeForest engaged in a new line of scientific development with a view to finding a system which would improve upon the performance of that of Marconi. He and his associates formed the DeForest Wireless Telegraph Company of America in 1902, and erected several coastal radio stations in the United States along the Atlantic Seaboard and on the Great Lakes for the experimental and commercial development of marine radio. The endeavors of this company to establish a commercial communication service gave stimulus to American effort in the radio field. The company was reorganized in 1904, under the name of the American DeForest Wireless Telegraph Company, and maintained several subsidiary companies in the United States. The company equipped many ships of the American Merchant Marine and installed land stations in the principal American seaport cities, as well as at Cleveland, Buffalo, Chicago, St. Louis, Kansas City, New Orleans, Port Huron, and several cities in the State of Colorado.

During the period of 1904 to 1906, several unsuccessful attempts were made to conduct an overland radio service in competition with the wire lines between cities in the Middle West, but the art had not developed technically to the point at which a satisfactory and continuous service could be rendered. The business assets and patent rights of the DeForest Company were absorbed by the United Wireless Telegraph Company of America, which was organized in the summer of 1907.

Professor Fessenden. Professor Reginald Fessenden was one of the outstanding contributors to the technical development of radio. He conceived many new principles and new ideas in the period from 1901 to 1910 and is today generally credited with having been ahead of his time. The majority of his inventions did not enjoy practical application until 1913, when new discoveries were made in connection with the three-electrode vacuum tube. His conception of the heterodyne receiver was one of the early and revolutionary contributions to technical development. He also foresaw the increased efficiency of the continuous-wave transmitter employing the high-frequency alternator as against the limitations of the spark transmitter used by Marconi and DeForest, having obtained the first United States patents for continuous-wave transmission systems in 1902. He was also a pioneer in the development of the radio telephone and the first to conceive the value of the 500-cycle high-frequency spark transmitter in increasing the efficiency of spark transmission and reception. With the aid of Pittsburgh bankers, Fessenden organized the National Electric Signalling Company in 1903 and proceeded to erect a large experimental radio plant and laboratory at Brant Rock, Massachusetts, with the view of developing the art technically and establishing transoceanic communication with a corresponding station erected by that company at Machrihanish Bay, in Scotland. Throughout its existence, the National Electric Signalling Company's efforts and activities in the radio field were devoted primarily to experimentation and technical development, although some apparatus produced by the company was sold to the Government.

Massie Wireless Telegraph Company. Walter Massie, one of the early experimenters in the United States radio field, organized the Massie Wireless Telegraph Company in 1905. This company erected stations along Long Island Sound, at Wilson's Point, Conn., New London, Conn., Chatham, Mass., Block Island and Providence, R. I., Montauk, N. Y., Point Judith, R. I., and Bronx, N. Y., for establishing wireless communication with ships in those waters. The marine operations of this company later were taken over by the Marine Transmission Company. The Massie Company was successful in obtaining contracts from the United States Government for the supply of radio equipment from 1905 to 1912, during which time several patents were applied for in the United States Patent Office. In 1912, the company decided to discontinue commercial operations, and its assets were purchased by the Marconi Wireless Telegraph Company of America.

Other important developments. In 1902, C. D. Ehret and others, of Philadelphia, formed the Continental Wireless Telegraph and Telephone Company, but this company achieved no importance in the radio industry and soon ceased operations.

In 1902, Harry Shoemaker and his associates formed the International Telegraph Construction Company for the exploitation of the Shoemaker radio inventions. This company manufactured and sold radio apparatus chiefly to the United States Government and foreign governments. The radio devices made by this company showed marked progress in electrical and mechanical construction and embodied many notable innovations in radio design. But business lagged and, in 1908, its assets were purchased by the United Wireless Telegraph Company of America.

When the United Wireless Telegraph Company of America purchased the assets of the defunct American DeForest Wireless Telegraph Company and the International Telegraph Construction Company in 1908, it undertook aggressively to develop radio communication in the American Merchant Marine. It continued to expand its activities in the marine field until, in 1911, it too experienced business difficulties. At this time, the company was involved in patent-infringement litigation with the Marconi Wireless Telegraph Company of America. The United Company submitted to a consent decree finding infringement of the Marconi patents in 1911, and its assets were purchased in 1912 by the Marconi Wireless Telegraph Company of America.

First attempts to develop an overland radio-telephone service. Dr. DeForest severed his connection with the American DeForest Wireless Telegraph Company in the later part of 1907, and shortly thereafter organized the Radio Telephone Company of New York for the exploitation of such of its patents as had not been assigned to the United Wireless Telegraph Company of America. The Radio Telephone Company of New York endeavored to operate an overland radio-telephone service between New York, Philadelphia, Albany, Cleveland, Chicago, Detroit, and Duluth. It found itself unable to compete with the performance of wire-telegraph lines. In 1909, this same company conducted experiments with the arc type of transmitter, both for radio telegraphy and

telephony, achieving some experimental results. But it became involved in patent-infringement suits brought by the Fessenden interests and ceased operation in 1911. DeForest later joined the laboratory staff of the Federal Telegraph Company of California.

Discovery of the vacuum-tube detector. It is important to note that, in the years 1906 and 1907, Dr. DeForest made the chief contribution to the future progress of the radio art in the form of a vacuum-tube detector known as the "DeForest audion." Two years prior, in 1905, Professor J. Ambrose Fleming of England had developed a two-element vacuum tube. This high-frequency rectifier of Fleming's proved to be one of the more stable types of receiving detectors so far developed, combining with its stability a marked degree of sensitivity to electromagnetic waves. DeForest improved the capabilities of the Fleming tube by inserting a third element, called a "grid," between the filament and the plate of the Fleming valve.

Some of the DeForest tubes of the earliest type evidenced unusual capabilities as "detectors" of electromagnetic waves, but it is important to observe that, up to 1914, the three-electrode, or DeForest, tube had little practical application. To function as detectors, such tubes required a rather critical but partial vacuum to make them operate correctly, and a given performance could hardly be duplicated from day to day. It was the discoveries and announcements in 1914 of E. H. Armstrong, a private investigator, and in 1915 of Doctor Irving Langmuir, of the General Electric Company, and work which was simultaneously carried on by the Western Electric Company in the three-electrode vacuum-tube field that gave the DeForest tube tremendous commercial impetus.[1] Nevertheless, DeForest's initial discovery constituted a supreme invention, accounting in a very large measure for the tremendous progress which has taken place in the radio field during the past 20 to 25 years. Other important discoveries which changed the trend of the art were the disclosures by E. F. W. Alexanderson, of the General Electric Company, early in 1914, of a method for modulating the high-frequency output of a vacuum-tube generator and, in March, 1915, of the tuned radio-frequency system of radio reception.

It should be noted that, in 1912, the patents covering the DeForest audion tube were vested in DeForest himself, that the Fleming Valve patents were owned by the various Marconi companies, and that these two devices were in a patent conflict from the beginning To connect

---

[1] This statement is expressed in the language of the art as of the date these two important discoveries were publicly announced Both of these inventors were considered pioneers in the field of their respective developments, but the regenerative circuit and high-vacuum tube patents went through extensive litigation over a period of years, and both were invalidated by court action—the Armstrong patent on October 6, 1927, by the Circuit Court of Appeals, Third Circuit, decree affirmed by the Supreme Court of the United States, priority being awarded to DeForest; and the Langmuir patent by a decision of the District Court of Delaware on April 28, 1926, decree affirmed by the Circuit Court of Appeals for the Third Circuit October 7, 1929, reversed and held valid by the same court on November 11, 1930, and invalidated by the United States Supreme Court in 1931.

the DeForest tube in a characteristic tuning circuit constituted a violation of the Marconi patents, and likewise the Marconi Company could not use the DeForest tube without infringing the DeForest patent rights. This situation accounts somewhat for the delay in putting the DeForest tube to commercial use.

Telefunken Company of Germany. The year 1909 witnessed the entrance of the Telefunken Company of Germany into United States radio operations. This company organized subsidiaries in the United States: the Telefunken Wireless Telegraph Company of the United States and the Atlantic Communication Company. The first-mentioned company operated a shore station in New York City for communicating with German vessels entering New York Harbor equipped with the Telefunken radio system.

Discovery of crystal detectors. In 1906, G. W. Pickard and General H. H. Dunwoody, of the United States Army, made important discoveries in the field of crystals, determining that an artificially compounded element known as "carborundum," or others such as zincite and silicon, possessed rectifying properties and could therefore be used as radio detectors. Pickard was a specialist in this field, and in later years he and his associates formed the Wireless Specialty Apparatus Company for the manufacture and sale of devices embodying his inventions.

Poulsen Wireless Corporation. In 1910, the Poulsen Wireless Corporation was formed in the United States for the exploitation of the Poulsen-Pedersen inventions, with respect to the continuous-wave arc-transmitting system. In 1911 and 1912, this company began the design and construction of arc-transmitting stations for ultimate installation at San Francisco, Los Angeles, Portland, and Honolulu. Other stations were erected at Fort Worth and El Paso, Texas. Communication was established eventually between these points within the limitations of the art at that time, but the service was not of a character to compete seriously with land lines and cables. These trials did indicate, however, that the continuous-wave system of radio-telegraph transmission provided technical benefits that were not obtainable from the spark system.

Federal Telegraph Company of California. Subsequently, the Poulsen Wireless Corporation transferred all its rights to the Federal Telegraph Company of California. The latter company had been organized for the conduct on the Pacific Coast of a transpacific and intercity communication service and for the sale of radio apparatus to the Government and to shipowners. During the First World War, the Federal Telegraph Company constructed several high-power stations for the United States Navy at San Diego, Pearl Harbor, Cavite in the Philippines, and Darien in the Canal Zone; also, in the Island of Guam, in San Juan, Puerto Rico, and, in the last year of the war, a very powerful station at Bordeaux, France.

Wireless Improvement Company—Colonel John Firth. In 1911, Colonel John Firth organized the Wireless Improvement Company for the sale of specialized radio devices. The company sold mainly crystal detectors manufactured under the Pickard patents, copper-plated high

voltage condensers, and several other accessories useful in radio communication.

Kilbourne and Clark Manufacturing Company. In 1912, the Kilbourne and Clark Manufacturig Company was organized in Seattle, Washington, for the manufacture, sale, or lease of radio apparatus, using the patents developed by Frederick Simpson. This company installed apparatus on ships, mainly those plying the Pacific Coast, and erected land stations in the United States and Alaska. During the war, it produced some equipment for the United States Government and for foreign governments. The company ceased operations in 1920.

Emil J. Simon. Emil J. Simon, an engineer who had seen duty with the Radio Telephone Company, the Wireless Improvement Company, and the National Electric Signalling Company, formed a personally owned company in 1915, securing a contract from the Navy Department in that year for radio transmitters of the quenched-spark type and also for receiving apparatus. This company manufactured additional apparatus for the United States Government during the war. After the war, Simon organized another company, the Intercity Radio Company, and erected a number of stations in the eastern and western parts of the United States in an endeavor to conduct an intercity radio-communication service. This service was discontinued after a time, however, and Simon later reëntered the field with a series of stations for communication with ships in the Great Lakes. This latter company ceased operations in 1930.

Status of Radio Communication in 1912

The year 1912 was a pivotal period in the technical and commercial development of radio communication in the United States The spark transmitter and the crystal receiving detector, both inefficient because of inherent technical limitations, held sway in commercial operations. The DeForest audion, although promising, had seen but little commercial use. Commercial and engineering circles acknowledged the necessity for some new technical developments giving higher operating efficiency; otherwise the art would be limited to marine communication. It was evident in 1912 that there was need for more powerful transmitters of the continuous-wave type, more sensitive receiving apparatus, and more selective receiving apparatus, so that the reliable range of communication could be increased.

Fessenden had forecast in patents issued in 1902 and had also demonstrated the improved performance that might be expected from a generator of high-frequency continuous waves. He sought to interest the General Electric Company in the construction of such a machine as early as 1901, but it was not until September, 1906, that this machine was delivered for experimental trials. The final product represented the joint efforts of the experts and consultants of the General Electric Company and the Fessenden interests. Hence, United States genius is prop-

erly credited with having made the first distinct departure from the old-time spark system.

Dudell, an English scientist, and Poulsen, a Danish scientist, performed promising experiments with the oscillating arc in the period prior to 1910, but the arc did not generate continuous waves of constant amplitude, and it could not, therefore, be expected to give the efficiency and operating results of the high-frequency alternator.

Until 1912, commercial and technical effort had been directed almost solely toward the development of marine radio communication—that is, between ships at sea and between ships and the shore. The Marconi Wireless Telegraph Company of America, having acquired the assets of the United Wireless Telegraph Company, held the dominant position in the field of American radio marine communications. The Radio Telephone Company had ceased operations; the National Electric Signalling Company was conducting experiments at its laboratories at Brant Rock, Massachusetts; and the Massie Wireless Telegraph Company, for commercial reasons, was on the point of going out of business. The Federal Telegraph Company of California was experimenting on the Pacific Coast and elsewhere, endeavoring to conduct intercity and transpacific radio communication. Several other American companies, which have not been mentioned—such as the Clarke Wireless Telegraph Company of Detroit, the Stone Telephone and Telegraph Company, the American Wireless Telegraph Company, and the Collins Wireless Telephone Company—had ceased operations by this date, leaving the Marconi Company, commercially speaking, supreme in the field.

Very little had been accomplished prior to 1912 in the way of establishing transoceanic radio-telegraph communication. Marconi had experimentally transmitted signals from Poldhu, Cornwall, to St. Johns, Newfoundland, in 1901. Fessenden established occasional contact with his corresponding station at Machrihanish Bay, Scotland, in 1905, but the Scotland station was destroyed by a storm in 1906 and experiments were discontinued. In 1909, Marconi's Wireless Telegraph Company, Ltd., of Great Britain, in conjunction with the Marconi Wireless Telegraph Company of Canada, had established a commercial radio circuit between Glace Bay, Nova Scotia, and Clifden, Ireland.

As the distance between these stations was but approximately 2000 miles, the technical problem of spanning the gap was not so great as that encountered by those who had sought to transmit signals from the Atlantic Seaboard of the United States directly to England.

The Turning Point in United States Radio Development

A good deal of doubt was expressed in 1912 as to whether radio would ever render a service comparable to that given by wires or cables. The limitations of the art were painfully obvious. Then, just subsequent to 1912, physicists and engineers produced a series of major inventions, new discoveries that eventually revolutionized prior practices in the radio-transmitting and receiving fields.

Discoveries of E. H. Armstrong. A tremendous revitalization was given to technical development when, in 1914, E. H. Armstrong, conducting independent research and experiments at Columbia University, New York City, disclosed the actual phenomena taking place within the three-electrode vacuum tube when used as a detector, oscillator, and amplifier The accomplishments of Armstrong spurred on other investigators, whose works resulted in numerous inventions and discoveries connected with the operation of the vacuum tube.

Armstrong's experiments in 1913 led to the commercial evolution of the so-called "regenerative receiver," one of the principal inventions of the radio art. Armstrong found that the DeForest audion possessed a property which no one had theretofore noted, namely, that the signals received from a distant transmitting station were repeated in amplified form within the tube. He observed, therefore, that a simple connection between the output and the input circuits of the vacuum tube would amplify enormously the radio signals that were in process of detection within it. Thus the audion became at least 5,000 times more sensitive as a detector than any prior detecting mechanism. Simultaneously, the circuit gave increased selectivity, which is the ability to eliminate interfering signals. Armstrong also found that, if the input and output circuits of the audion were coupled closely enough, the entire system went into a state of self-oscillation. It therefore became a self-heterodyne, or "beat receiver," for the detection of continuous-wave radio-telegraph signals. This discovery made practically operative the Fessenden heterodyne principle, the patent for which had been applied for in 1905

Dr. DeForest already had observed that his audion could be used for amplification of radio signals after they had passed through the detector bulb and were within the realm of audio frequencies. Public announcement of his audio-amplifying circuit was made before the Institute of Radio Engineers on December 3, 1913. Engineers soon found that the combination of the vacuum-tube audio amplifier with the Armstrong regenerative detector provided a signal audibility at the receiving station which was utterly impossible of attainment by any other radio-receiving system. Armstrong astonished scientific and amateur radio circles by demonstrating, in 1913, that a single audion bulb could be used for the detection of continuous-wave radio-telegraph signals over distances of several thousand miles under favorable atmospheric conditions.

Perfection of the vacuum tube—Dr. Irving Langmuir. In 1915, following the Armstrong discovery, Dr. Irving Langmuir, of the General Electric Company, announced the perfection of the high-vacuum, or so-called "hard," tube. Prior to this disclosure, the art was familiar only with the DeForest type of tube, which depended for its operation as a detector upon gas ionization. This was changed into a tube not at all dependent upon ionization, the gas being exhausted to a high degree not only from the space within the glass envelope but also from the glass walls and from the electrodes of the tube. The tubes were made stable for radio operation and were capable of handling much greater outputs

than the former types of tubes. This discovery opened the possibility of employing the vacuum tube as a means of transmission. Thus, at a time when it seemed that the radio art had progressed technically as far as it could go, important discoveries were made which led research into entirely new paths.

Important inventions held by opposing interests. It is important also to note that these important inventions and their associated circuits were held by opposing interests. The American Marconi Company owned the fundamental Marconi patents which dominated the art, including the Fleming valve patent. The DeForest interests owned the three-electrode vacuum-tube patents, and E. H. Armstrong, a private investigator, the regenerative- and oscillating-tube patents and the superheterodyne patents. The Fessenden group had the continuous-wave and heterodyne patents. The high-vacuum patent was applied for by Doctor Langmuir on behalf of the General Electric Company and by Doctor Arnold on behalf of the Western Electric Company. The tube-modulator patents and the tuned radio-frequency patents belonged to the General Electric Company. It was evident, even in these early years (1912 to 1915), that, without some patent compromise or licensing arrangements between the patentees, these inventions could not be put to commercial practice. There were numerous other cases of patent conflict also.

The Evolution of the High-Power Transoceanic Radio Transmitter

Further progress was made in the development of continuous-wave transmitters of the arc and high-frequency alternator types in the period from 1912 to 1918.

Tests prove superiority of continuous-wave method. The early experiments in the United States of the Poulsen interests with the Poulsen arc generator have already been noted. Further conclusive demonstration of the superiority of the continuous-wave method of transmission and reception, as first conceived by Fessenden, was effected in tests made at the Government's station at Arlington, Virginia, in February and March, 1913, where a Fessenden rotating spark transmitter, in conjunction with the heterodyne receiver, had been installed. An elaborate series of tests was conducted by the Government and by the Fessenden interests with naval vessels and other radio stations, which proved beyond cavil that the continuous-wave system would ultimately supersede the spark system. This fact was all the more demonstrated when, a little later, the Government installed a Poulsen arc continuous-wave transmitter at that station, in conjunction with the Fessenden heterodyne.

High-power transoceanic stations erected. In 1914, the Atlantic Communication Company, a subsidiary of the Telefunken Wireless Telegraph Company, of Germany, began the erection of a high-power transoceanic station at Sayville, Long Island, using the Joly-Arco high-frequency alternator system developed by German engineers. In the same year, the High Frequency Machine Company, of Berlin, began the

erection of another high-power station in the United States at Tuckerton, New Jersey, using the Goldschmidt high-frequency alternator, another continuous-wave transmitting system developed by German interests. This Tuckerton station, however, was being erected by the Germans on behalf of a French communications company. Both the Sayville and Tuckerton stations established communication of an intermittent character with their corresponding stations in Europe. Transoceanic radio was not yet able to compete seriously with cables.

Prior to the entrance of the United States into the First World War, the Sayville station had been used for the dispatch of some commercial traffic to Nauen, Germany. Likewise the Tuckerton station dispatched a small amount of traffic to a corresponding station at Eilvese, Germany. The service rendered by these two stations was in no sense competitive with the cables, although it was again demonstrated that the continuous-wave system of transmission possessed inherent benefits that could not be obtained with the Marconi spark system.

In 1913, the Marconi Wireless Telegraph Company of America, in conjunction with Marconi's Wireless Telegraph Company, Ltd., of Great Britain, also laid plans for an international transoceanic communication service, erecting high-power transmitting stations for these services at New Brunswick, N. J., Marion, Mass., Bolinas, Calif., and Kahuku, in the Hawaiian Islands. It should be noted that the efforts of the Marconi Company and of the two German radio companies above mentioned were in the nature of "cut-and-try" experiments, to determine the extent to which radio could be employed for commercial communication over distances in excess of 2,000 miles. The experiments made at all these stations were promising, but the apparatus used by the German interests in the United States, particularly the radio-receiving equipment, infringed on fundamental patents of the American Marconi Company, and it was obvious that these infringements must come to an issue.

Government authorities take over control of radio-communication facilities. While these transoceanic experiments were in progress, the United States Government, having witnessed the improved performance that resulted from the major discoveries of Fessenden, Fleming, DeForest, Armstrong, and others made in the art subsequent to 1912, began to develop for its own use apparatus embodying these inventions; and as early as 1914, it had assembled radio-receiving apparatus using these inventions. It was purchasing apparatus from suppliers that openly infringed the patents of Marconi and others. The Government foresaw, however, that, in letting contracts for such apparatus to suppliers, it faced a conflicting patent situation. None of these interests possessed the rights under a sufficient number of patents to supply these devices to the Government without infringement. Commercial radio interests faced the same situation. It was but a short time later (1917) that the United States declared war on Germany, and the Navy Department, by legislative authority, then took control of all United States radio communications, including the stations erected by the Marconi Company and by German interests for international communication. In fact, the Tucker-

ton station had been taken over by the Navy Department prior to our entrance into the war because of violation of the Neutrality Act. Later, the Sayville station was seized by the Alien Property Custodian.

New impetus to the industry. The pressure of the Government's war-emergency requirements caused the laboratories of some of the great electrical companies, including those of lesser manufacturers and individuals, to engage in the development of devices specifically designed for the Government's needs. This extraordinary and intensive activity gave tremendous impetus to the technical progress of the art but resulted in the creation of many more radio inventions that were held by widely scattered interests. It being apparent that the Government was faced with an irreconcilable patent situation in the procurement of radio apparatus, a "rider" was attached to the Naval Appropriations Act of 1918 which provided that manufacturers could bid on the Government's requirements for radio apparatus free from damages due to possible patent infringement, the patentee having recourse to the Court of Claims for any damages that he might have suffered as the result of such infringement.

The Marconi Wireless Telegraph Company of America, the Kilbourne and Clark Manufacturing Company of Seattle, the DeForest Radio Telegraph and Telephone Company, the National Electric Signalling Company, and the Federal Telegraph Company of California were the principal radio companies of the country when it entered the First World War, but approximately 20 additional manufacturing concerns organized themselves to supply apparatus to the Government for its various services, and many millions of dollars worth of radio equipment was produced during the war period under Government contract.

Results of legislation freeing Government of patent barriers. Having thus gained patent freedom by legislation, the Government specified radio apparatus embodying the finest inventions in the radio art, regardless of patent ownership. It was therefore able to put to practical use in its own radio stations and those which it had taken over apparatus far in advance of that available to any private or commercial radio interest. The stations of the American Marconi Company were employed for the dispatch of traffic connected with war operations to European stations, together with a limited amount of censored, commercial radio traffic. The Government installed high-power Poulsen arc transmitters in many of the naval stations, replacing the high-frequency alternator installation at Tuckerton, New Jersey, with one of these. It asked the General Electric Company to manufacture a high-frequency alternator of 200-kw. capacity for installation at the Marconi High-Power Station at New Brunswick, New Jersey, and it erected some other high-power stations necessary for its war operations. By these peculiar circumstances, it will be seen that, shortly after the time at which the radio art had developed some major inventions and was making plans for their application, the entire communication facilities of the industry passed for a period into the hands of Government authorities. All patent barriers were temporarily broken down and the property of all foreign

radio interests taken over. It was evident to all concerned that, whenever the properties of the Marconi Wireless Telegraph Company of America should be returned to it by the Government, neither the Marconi Company nor any other American interests could use the advanced apparatus which the Government had installed in these stations because of patent conflict. It was equally evident that the manufacturing companies which had been organized merely to supply radio apparatus to the Government under Government patent protection would be compelled to cease operations whenever patents should be returned to their prewar status of private ownership. Here was a problem that appeared to defy solution. We shall come later to a description of the way which was finally found to cut this Gordian knot.

The Rise of Radio Telephony and Broadcasting

Wireless-telephone communication established by Fessenden. No outline of the development of broadcasting in America, however sketchy, would do justice to the subject without reviewing certain early experiments in radio telephony, commencing with those of Reginald Fessenden. In 1903 and 1905, this pioneer established wireless-telephone communication between Washington and Annapolis; and in February, 1907, he gave a further demonstration of his system to Dr. Kennelly, Professor Elihu Thompson, and engineers of the Western Electric and American Telephone and Telegraph Companies. In 1906, both speech and music were transmitted from one of the Fessenden stations and heard at considerable distances.

DeForest experiments with an arc system. In 1907, Dr. Lee DeForest conducted a series of experiments for the Lackawanna Railroad, using an arc transmitter modulated by a microphone. Speech was successfully transmitted to a distance of 12 miles. DeForest equipped some vessels of the United States Naval Fleet with this system in 1907 and 1908, by means of which radio telephony was acomplished over short distances. In 1910, using an arc type of transmitter of his own design, DeForest transmitted opera selections given by Caruso and Destinn from the Metropolitan Opera House in New York City. This was simply a pioneer experiment evidencing nothing of a commercially practicable system. The arc system could never be made practical for commercial radio telephony.

Status of radio telephone in 1912. The arc transmitter is not, however, inherently suited to radio-telephony. It cannot satisfy the requirements of commercial practice because, first, it does not generate a "pure" continuous wave and, second, no one has been able to devise a suitable method of modulating the output of the arc generator by a microphone so as to give sufficient variation in amplitude to be heard at any considerable distance. Thus, the radio-telephone experiments conducted prior to 1912 employed crude and inefficient apparatus having practically no commercial utility. Reviewing the progress of radio telephony during 1910, *The Electrical World*, in the issue of January 5, 1911, said in part:

Wireless telephony in America has suffered from over-exploitation and underequipment. Promises ranging from opera music at 200 miles to telephony between New York and Paris have been very lacking in fulfillment. The majority of workers in this branch of wireless signalling have either feared or been unable to break away from the "arc-and-microphone" type of senders and the general lack of progress is probably the result of this.

Advent of the vacuum tube in radio telephony. Prior to 1912, the vacuum-tube transmitter was still unknown; but following E. H. Armstrong's announcement of the regenerative and oscillating vacuum-tube circuit in 1914, the opinion prevailed that, ultimately, the vacuum tube would become the preferred form of high-frequency generator for radio transmission because it generates a "pure" high-frequency wave and also permits effective modulation of such a wave by a microphone. This general view seemed nearer fulfillment when the high-vacuum tube was announced, thereby making possible a vacuum-tube transmitter of large power output; but it was several years after that announcement, in 1915, of the high-vacuum tube before such large power tubes were made available. From 1914 on, important experiments were conducted abroad, as well as here, with the vacuum-tube transmitter, but the apparatus was crude and of limited power. The art needed tubes of greater output, longer life, and greater stability of operation. Intensive laboratory research made such tubes available from 1917, and today single tubes give an output of 100 kw. or more.

Further development of the vacuum-tube transmitter. Impetus was given to the early development of radio telephony by a brilliant experiment made by the American Telephone and Telegraph Company in 1915, in conjunction with the Navy Department at the Naval Radio Station at Arlington, Virginia, where a battery of vacuum-tube oscillators was assembled for experimental work. Tubes of only a few watts output were available at that time, but a sufficient number were mounted together in racks to give an aggregate output of several kilowatts of high-frequency energy. Telephone conversations directed from the Arlington station were heard at times in Paris and in the Hawaiian Islands, where listening posts had been established.

During the First World War, the Government had developed vacuum-tube transmitters for portable military work. By 1917, the General Electric Company had perfected and produced transmitting tubes capable of a 250-watts output, which were assembled in radio telegraph and telephone circuits. In 1919, the General Electric Company installed a powerful vacuum-tube radio-telephone transmitter on the *S.S. George Washington*, the ship which carried President Wilson to the Peace Conference. Telephone communication was established with the New Brunswick and Belmar, New Jersey, stations of the American Marconi Company up to distances of 1,100 miles in daylight and across the Atlantic by night

Broadcasting experiments—DeForest. In 1916, Dr. DeForest renewed his radio-telephone activities in the transmission of speech and music from a station at High Bridge, New York, using the vacuum-tube

transmitter At the same time, a powerful broadcasting transmitter was being developed at the radio laboratory of the College of the City of New York, by Dr. Alfred N. Goldsmith and Julius Weinberger. This was operated nightly, using phonograph records and local speech, and was heard by many amateurs within a range of hundreds of miles

The possibilities of this new method of disseminating entertainment to the home had not yet reached the layman's mind. It was a novelty enjoyed by a few radio amateurs familiar with the technicalities of the art. The final link—the stimulation of popular interest and that of developing receiving apparatus for the home simple enough for anyone to operate and, at the same time, efficient in reception—was yet to come The DeForest station, as well as other commercial and private stations, was closed down when the United States declared war on Germany in 1917, but DeForest recommenced this activity in 1919, when the Government ban was lifted, establishing a studio in New York. Again the speech and the music thus transmitted were appreciated only by radio amateurs; however, since the station interfered with the operation of radio-telegraph stations in the vicinity of New York, DeForest's work was brought to a close. The transmitter was then moved to San Francisco, and broadcasting experiments were continued in that city into the summer of 1920.

First news bulletins transmitted. The DeForest Radio Telegraph and Telephone Company sold amateur and experimental radio-telephone transmitters of low power during this period, and one of these sets was purchased by the *Detroit Daily News* and employed for sending out news bulletins, which were heard by radio amateurs. This activity started in August, 1920, and has been a feature of this newspaper's radio activities since that time. The operation of this station created local amateur interest, but the nation-wide furor over this new development was yet to come.

Radio-telephony developments during the First World War—Westinghouse Electric and Manufacturing Company. Throughout the period of the First World War, radio development was proceeding in the laboratory of the Westinghouse Electric and Manufacturing Company at Pittsburgh, Pennsylvania. Because of the important work done by that company, the Government permitted it to continue certain radio activities without interruption throughout the war at two radio stations in Pittsburgh, about 5 miles apart. Dr. Frank Conrad directed the laboratory development, and Dr. H. P. Davis was in charge of the Westinghouse Company's War activities. Conrad's work was closely coördinated with that of the Signal Corps; his researches developed new ideas that constituted important advances in the art. At the close of the war, Dr. Conrad continued his experiments in radio telephony between these two stations, transmitting musical programs, talks, and baseball and football scores which aroused the interest of radio amateurs and some laymen in that district.

The first public broadcasting service—Davis. An enterprising Pittsburgh department store, the Joseph Horne Company, sponsored a small

newspaper advertisement announcing the sale of radio receivers for reception of phonograph music being broadcast by the Westinghouse Company. Dr. Davis sensed that the public might then be receptive to this new means of disseminating entertainment if broadcasting could be adapted to their need with the utmost simplicity. As a result, early in 1920, plans were put into effect by Davis and Conrad for the installation of a more powerful radio-telephone transmitter, which was ready for operation the following autumn. A public broadcast service was commenced on November 2, with the historic broadcasting of the returns of the presidential election. It continued with a regular daily scheduled program from that date. Dr. Davis is therefore properly credited with being the first instigator of an organized public broadcast service. Because of the interest excited, Westinghouse produced for the Radio Corporation some simple receivers for operation by laymen. The instant success of this station's operations led the Westinghouse Company to erect more stations —WBZ at Springfield, Mass., in September, 1921; WJZ at Newark, N. J., on October 12, 1921; and KYW at Chicago, Ill., on November 11, 1921.

By the spring of 1922, the operation of these stations produced a nation-wide enthusiasm, and beginning with the summer of 1922, new broadcasting stations were erected by various interests throughout the nation. From the few stations in operation in 1921, the number increased to nearly 300 by the close of 1922, and between 500 and 600 broadcasting stations kept in operation until the middle of 1926. By the middle of 1927, the number had grown to 700.

Status of the Radio Industry in 1919

Reference has already been made to some of the numerous improvements in radio apparatus that were patented by American inventors during the period from 1912 to 1919, and particularly during the First World War. It has been shown how the continuous-wave system of radio transmission, combined with heterodyne reception as conceived by Fessenden in 1902 and used experimentally by him throughout the period 1901 to 1912, was put to practical use by the Government in 1913 (and subsequent thereto), demonstrating its improvement over the spark transmitter. It has been explained how the experiments made with the vacuum-tube transmitter prior to 1919 revealed its destiny as the ultimate form of high-frequency generator for radio-telephone and telegraph transmission. Already recounted is Armstrong's announcement of the regenerative receiver in 1913 and of the superheterodyne in 1918, as well as Alexanderson's disclosure of the tuned radio-frequency circuit in 1916, which paved the way for tremendous progress in the efficiency of radio-receiving apparatus. We are therefore aware that, throughout the period from 1912 to 1919, research physicists of the large electrical companies, engineers attached to the staff of the Army and Navy Departments, and laboratories of the great universities were all engaged in experimenting with new radio developments. Thousands of patents were applied for and their ownership was widely scattered. We are also familiar with the

action taken by the Government in overcoming this complex patent situation during the First World War. The story of radio patents proceeds.

Success of high-frequency generators—radio begins to compete with cables. In 1917, an event took place which was destined to change the history of radio development in the United States. Prior to our entry into the First World War, the General Electric Company, at the invitation of the Navy Department, had installed, for communication with Europe, a 50-kw. Alexanderson high-frequency alternator at the high-power station of the Marconi Wireless Telegraph Company of America at New Brunswick. This machine incorporated many improvements not evident in the design of prior types of high-frequency alternators. The first demonstrations of this apparatus were successful, and it was at once placed in continuous service, handling a large amount of Government radio traffic during the war. It was recognized, however, that a high-frequency generator of greater output would be necessary for continuous and reliable transoceanic communication. The General Electric Company immediately began the manufacture of a 200-kw. alternator, which was installed at New Brunswick in 1918. The new alternator had several outstanding and novel features. It was connected to an aerial known as the "multiple-tuned antenna system" which represented a wholly new design in the art and gave an over-all efficiency of about seven times that procured from any other high-frequency alternator system. The system operated so satisfactorily that it was pronounced by the Navy Department the most efficient transmitting system for international communication developed to date. For the first time in the history of the radio industry, it was believed that radio could compete with the cables in world-wide communication.

Necessity seen for an American organization to control radio communication in the United States. Several years prior to 1919, the Navy Department had been fearful that control of international radio communications from America would fall into the hands of foreign radio companies or foreign governments. Knowing that the Marconi Wireless Telegraph Company of America was a subsidiary of the British Marconi Company and that the latter company seemed destined to control a greater part of the international radio-communication circuits, the Navy formulated a policy which enabled the control of the American terminals of these circuits to remain in American hands. It had observed the patent complexities that existed in the art in 1919 and even in prior years, indicating quite clearly that no single American company then existent could provide the Government or itself with apparatus embodying the latest improvements in the art without infringing on the patent rights of some other patentee. It was aware that the General Electric Company was conducting negotiations with the British Marconi Company for the purchase by the latter of the Alexanderson high-frequency alternators for international communication. The experience of the First World War had shown the necessity of having radio stations capable of transmitting directly to all points of the world without supervision or censorship on

the part of other nations. It was therefore the belief of Government officials that such stations should be in the control of the Government or of private interests that were wholly American-owned. This was deemed necessary as a safeguard, not only in the event of future wars, but to the development of our international commerce as well. In arriving at these conclusions, the Government officials could not have been unmindful of the dominating position of Great Britain in transoceanic cable communication.

In April, 1919, the Acting Secretary of the Navy of the United States wrote to the General Electric Company requesting that the company confer with representatives of the Navy Department before entering into any final agreement with the British Marconi interests with respect to the high-frequency alternator. A conference was called in New York City a few days later, at which time the Government representatives pointed out that, if the General Electric Company should dispose of the Alexanderson apparatus to foreign interests, such interests would be able to maintain a monopoly of world-wide communication for an indefinite period. The situation was considered critical because the Marconi companies were seeking further concessions throughout the world. If successful, such action would give the British Government and the British companies a practical monopoly of international communications. One Government representative offered the suggestion that they form a wholly American-owned company that would be in a position to treat with the British Marconi Company on equal terms. Since the American Marconi Company was the leading communications company in the United States and controlled, among others, the dominating Fleming-tube patent, it was suggested, in the course of the discussion which followed, that a union of the facilities and patent rights of these two companies might become the nucleus of an American organization which would keep control of United States radio communications in United States hands.

Negotiations between American and British interests. Representatives of the General Electric Company then approached the British Marconi Company to determine whether they would be receptive to such a proposal. Its acceptance would mean, in effect, that the British Marconi Company would dispose of its interests in the American Marconi Company. The British Marconi Company, having witnessed the determined opposition of the United States Government officials to British domination, acceded to the suggestion; and in the autumn of 1919, tentative arrangements were agreed upon by the British Marconi Company and the General Electric Company. These tentative arrangements had the approval of officials of the Navy Department.

Radio Corporation of America. The General Electric Company was equally solicitious with the Navy Department in the formation of an American-owned radio company, for it wanted a commercial outlet for its patents and inventions in the radio field It was convinced that its patent rights were insufficient to enable it to go forward with a comprehensive commercial program without infringement of other patent rights and that other interests were in possession of inventions necessary for

the commercial success of its own system. Again, it had noted the large investment made by the American Marconi Company in patents, stations, plants, and equipment, and foresaw that these facilities could be put to immediate use for the commercial exploitation of the General Electric inventions As a result of these overtures, the Radio Corporation of America was formed on October 17, 1919, representing a union of the patent rights and interests of the General Electric Company and the Marconi Wireless Telegraph Company of America. The two companies exchanged cross-licenses under their respective patents, and the Radio Corporation purchased a quantity of Alexanderson high-frequency alternators for rehabilitation of the transoceanic radio system which it had acquired from the Marconi Company. Thus the American Marconi Company was freed from British control.

Coöperation between the General Electric Company and the Radio Corporation of America. The articles of incorporation of the Radio Corporation of America were so drawn as to insure that 80 per cent of its stock would at all times be in the hands of loyal American stockholders. In the execution of the cross-licensing agreement between the General Electric Company and the Radio Corporation of America, the normal business fields of the two companies were given logical consideration. The natural field of the General Electric Company was not that of communication, particularly radio communication; it was engaged primarily in selling electrical devices for purposes other than radio, but its scientists were conducting electrical research and making discoveries applicable to the radio field as well as to their own spheres of operations. The Radio Corporation of America, on the other hand, had the radio stations and business of the Marconi Company and a highly specialized organization well versed in the problems and conduct of radio-communication business. The Radio Corporation had no manufacturing facilities and but limited research facilities, while the General Electric Company possessed both of these in large measure. Hence, under the terms of the agreement, the General Electric Company was to do the manufacturing and retain nonradio rights under the radio patents that had been joined in the formation of the Radio Corporation of America, while the latter company obtained the rights to use and sell radio devices under these patents. The General Electric Company promised to continue its research activities

The patent situation in 1919. Here was the first effort toward removal of the patent deadlock that existed throughout the industry in the United States at the end of the First World War. No individual patentee, radio-manufacturing company, or electrical company could, in 1919, build radio-transmitting and receiving apparatus equal in efficiency to that installed and put to use by the Government during the war period without infringement of adversely held patent rights. For example, the DeForest audion was covered by the Fleming patent, owned by the Marconi Wireless Telegraph Company of America, as well as by DeForest's patents.

Important research work on the elimination of static in transoceanic communication had been conducted by R. A. Weagant and others for the Marconi Wireless Telegraph Company of America, upon which patents were pending. Langmuir's high-vacuum-tube developments, the Alexanderson alternator and tuned radio-frequency inventions, and the broad patent on the modulator systems were owned by the General Electric Company. The regenerative and superheterodyne circuits were owned by E. H. Armstrong. The negative grid bias, an important invention of F. Lowenstein, was owned by the American Telephone and Telegraph Company, which also owned the Arnold rights in the high-vacuum tube; and in 1917, this same company purchased exclusive rights to the DeForest audion and other DeForest patents, except for certain limited reserved rights. The American Telephone and Telegraph Company had developed, in its own laboratories, important improvements in vacuum-tube receivers and vacuum-tube transmitters, including a practical tube-modulator system. It developed some basic inventions applicable to all phases of the radio field. Fundamental patents, pertaining to the superheterodyne and other radio inventions also, were issued to other inventors, such as Frederick Vreeland and John Hays Hammond. Then there were the important Fessenden patents already mentioned. Thus, although the agreements between the General Electric Company and the Marconi Wireless Telegraph Company of America were important steps toward removing the United States patent deadlock, the deadlock was not completely removed.

It should be noted that, prior to 1912, radio development was almost wholly in the hands of companies formed primarily and exclusively for exploitation of the radio field. But just prior to 1912 and subsequent to that year, we find, at the expense of some repetition, that the laboratories of the large electrical interests in the United States were beginning to investigate radio phenomena. Recognizing that the design of radio apparatus up to that time had been more or less upon the "hit-and-miss" principle, that the communication range of the systems then in use was limited, and that many basic inventions had been made which had not passed beyond the stage of an idea, these physicists and inventors took the entire technical situation under review and endeavored to obtain a better and more practical interpretation of the underlying physical laws The General Electric Company had done some development work in the high-frequency alternator field prior to 1912. From 1910 on, the American Telephone and Telegraph Company investigated the possibility of using the DeForest audion as an amplifier in land-line telephony and soon adopted it for overland long-distance telephone communication. The laboratory experts of the Western Electric Company and the American Telephone and Telegraph Company undertook aggressively the development of improved vacuum tubes in their application to radio as well at to telephone work; and, having acquired certain patent rights from Lowenstein and others, including DeForest, in 1917, in addition to many very important inventions developed in its own organization, the American Telephone and Telegraph Company, by 1919, was thus in a

position of patent strength in the radio field. The outstanding work in radio development by the General Electric Company between 1912 and 1919 has been already shown, so that there were three large interests in the field which possessed valuable and important patents, not to mention the many patents held by outside individuals.

Coöperation between the General Electric Company and the American Telephone and Telegraph Company. The American Telephone and Telegraph Company observed that other interests held valuable radio patent rights under which it required licenses to proceed with the development of an efficient and modern radio-communication system In January, 1920, the acting chief of the Bureau of Steam Engineering of the Navy Department wrote to the General Electric Company and to the Telephone Company urging an exchange of patent licenses in the vacuum-tube field, referring to the urgency for unlocking the patent situation in the vacuum-tube field as a "public necessity." Following extended negotiations, the Telephone Company and the General Electric Company entered into cross-license arrangements on July 1, 1920, the radio rights so secured by the General Electric Company being passed on to the Radio Corporation of America and the Telephone Company reserving to itself certain rights of the radio field.

Westinghouse interest in radio transmission. But the Westinghouse Electric and Manufacturing Company remained to be reckoned with. It is natural that a concern of such importance should have been actively seeking to safeguard its own future in the development of a great new industry such as radio.

It will be remembered that the Westinghouse Company had done important radio work for the Government during the war, at which time none had to reckon with patent restrictions That was a period of design and construction, however, rather than speculative research, and the contribution of Westinghouse to the Government's job in hand was considerable. In its close coöperation with the Signal Corps, the activities of the Westinghouse laboratory were directed principally at a practical application of the many radio developments then existent. Thus, though the war work of the Westinghouse Company will ever redound to its credit, it was not of a nature to place the company in a competitive position. It is understandable, however, that Westinghouse considered it had earned the right to participate in the further, peacetime development of the radio industry and that, recognizing a position of patent strength as the best guarantee of a competitive position in the future, it proceeded in that direction.

The astuteness with which Westinghouse acquired radio patents at the same time that it redoubled its own research activities gave ample evidence that that company was fully awake to the trend of development at that time and its future significance. First, a part ownership was bought in the International Radio Telegraph Company, successor to the National Electric Signalling Company, and a new International Radio Telegraph Company was formed in May, 1920. This brought to Westinghouse control of the Fessenden inventions, with which it proposed

to enter the fields of transoceanic and marine radio communication. However, a careful survey of the patent situation revealed that these were not sufficient, for, as yet, it had no rights in the field of vacuum tubes. The next step was to obtain an option on the Armstrong regenerative and superheterodyne patents, effected in October, 1921. Later, these patents were purchased outright.

Among other things, it was the plan of the Westinghouse Company to develop a high-frequency alternator for the International Radio Telegraph Company to be installed at Belfast, Maine, for international communication; but in planning this station, it soon developed that the Westinghouse Company's patent position was by no means sufficient, even after its acquisition of the International Company's patents. In developing the high-frequency alternator system, it had to avoid infringement of the Alexanderson-alternator patents of the General Electric Company. It doubted whether it could develop an antenna system equal in efficiency to the multiple-tuned antenna system of the General Electric Company. It investigated the Poulsen-arc system to determine whether it was feasible for international radio communication. Its subsidiary, the International Radio Telegraph Company, exchanged patent licenses with the Government under which the International Company secured a royalty-free license under the Poulsen-arc patents. It was obvious, however, that the arc transmitter could not compete with the highly perfected Alexanderson system.

Westinghouse had hoped to manufacture and sell radio transmitters and receivers for ship-to-ship and ship-to-shore radio-communication service, but when it came to the production of such apparatus, it found that the important patents were owned by outside interests.

In the field of vacuum tubes, it had no basic patents. It attempted to develop a vacuum tube that would not infringe on the Fleming and DeForest patents, but without success. It found that the patents relating to modulating schemes for radio telephony were covered by the patents of other interests—the American Telephone and Telegraph Company and the General Electric Company.

Westinghouse exchanges cross-licenses with the other three large interests. Its various patent purchases and developments, however, gave the Westinghouse Company a position of patent strength, since it was the owner of some of the principal inventions covering a continuous-wave system of radio communication; but it had no dominating, or "key," patent pertaining to vacuum tubes. It found itself dealing with a most confusing situation and came to the conclusion that further activity in a field having such diversified patent ownership was hazardous and certain to lead to litigation. It had already spent several million dollars, either outright or by obligation, only to be mired in the same confusion from which its competitors had already begun to extricate themselves by the process of cross-licensing. To proceed with the development of a radio-communication system, it needed rights under the American Telephone and Telegraph, General Electric, and Radio Corporation patents. Nevertheless, Westinghouse had provided itself with patents

that were also needed by the other companies. Hence, in 1920, when it was invited by representatives of the General Electric Company to discuss the patent difficulties which still existed in the radio industry, it was in a receptive mood to exchange cross-licenses with the Radio Corporation of America, the General Electric Company, and the American Telephone and Telegraph Company, and such agreements were executed in July, 1921.

The First Solution of the Radio-Patent Conflict

With the conclusion of the patent-licensing agreements between the Radio Corporation of America, General Electric Company, American Telephone and Telegraph Company, and Westinghouse Electric and Manufacturing Company, great steps had been taken toward enabling, for the first time, the construction and use of radio-transmitting and receiving apparatus that would enable radio to render to the American public a reliable communication service, free from palpable patent infringement. Without some such arrangement, development of the radio art in the United States would have been retarded for years and the public would not be enjoying the many new services now available.

Thus, in summary, when we view the situation as it existed in 1921, we find a circumstance in which three of the very large corporations in American industry, the Government, and many individual inventors faced an impassable patent deadlock in the commercial development of their radio inventions. We find a fourth organization, the Radio Corporation of America, which, having acquired the assets of the American Marconi Company, had placed itself in an important commercial position without the necessary patent rights to build a modern radio system. The patent conflict prevented any organization or individual from going forward with a comprehensive commercial program.

The agreements entered into between the members of this group permitted commercial and technical development to proceed apace. However, the patent conflict was not wholly removed by these intercompany cross-licensing agreements, for a number of important radio patents were held by outside interests under which the RCA later acquired rights to enable it to produce a clearly noninfringing system including the best-known apparatus and inventions. Nevertheless, the way was paved for a tremendous expansion of commercial and technical activities. A commercial outlet was made for the many inventions that had been made in the radio field in prior years.

It is often asked why it was necessary for one organization to be placed in a position where it could select the best of a large group of inventions and patents to develop a reliable system of space radio communication. The answer is that the inherent technical limitations of the radio art called for a coördination of the very best inventions known to the industry. Anything short of this would have resulted in inefficient and unreliable communication. Wartime experience had shown which was best; deliberate retrogression was unthinkable. Only the maximum

of efficiency, the maximum of sensitivity, and the maximum of selectivity—terms familiar to radio engineers—would afford satisfactory operation. Universal application of the art was limited because of the limited number of wave lengths available in the radio spectrum for transmission. The actual power of high-frequency currents dealt with at the radio receiving station is almost infinitesimal. Hence, to record and reproduce such signals, apparatus of the maximum sensitivity is esential; and to prevent interference between various transmitting stations, the maximum of selectivity is essential. Efficient transmission could be obtained only with continuous waves and, in radio telephony, only by the vacuum-tube transmitter. Efficient receiving systems came only from such inventions as the regenerative receiver, the tuned radio-frequency receiver, and the superheterodyne. The superheterodyne itself involved practically every fundamental radio patent known to the art, and these patents had widely scattered ownership.

The Development of Broadcasting Subsequent to 1921

Public enthusiasm for broadcasting aroused. The steps which led to the development of organized broadcast transmission service on the part of the Westinghouse Company in the autumn of 1920 and early in 1921 have been recounted.

In February, 1922, public interest in this new form of home entertainment grew to such heights that it created a national furor. No scientific experiment in history had produced such a high degree of public enthusiasm. The business of selling receiving apparatus for reproduction of broadcast entertainment expanded at a rate unparalleled in industrial history. Prior to 1921, the sale of radio apparatus other than that used for public radio-telegraph communication purposes was confined chiefly to the sale of radio parts and vacuum tubes to amateurs and experimenters for their personal use; but when lay interest was aroused by the early broadcasting activities, the demand for simplified radio receivers for home entertainment grew to such volume during 1922 to 1923 that, at times, manufacturing facilities were barely able to cope with the demand. Thus, the sale of radio receivers grew from a business of a few thousand dollars per annum in 1922 to hundreds of millions of dollars per annum subsequent to 1922.

Enormous growth of radio manufacturing—patent rights infringed. Sensing an opportunity for making quick profits, many radio-manufacturing companies were organized in the United States for producing and selling broadcast receivers to the public without regard for patent ownership. Infringement of patent rights on the part of these manufacturers was the order of the day. Individuals and organizations having no prior experience in the art engaged in the manufacture of receiving apparatus and component parts of radio sets on an unprecedented scale, for it was comparatively easy to take the inventions and patents that had been developed by others at great expense and to construct a receiving set that had sufficient public appeal for the moment. The shortage of

radio equipment enabled infringing radio receiving sets to be widely made and sold. As a result of these hectic and slipshod maneuvers, the market was soon flooded with merchandise. Overproduction, followed by liquidations, resulted in large losses. Technical design in the field of broadcast receivers was rapid. Receivers were rendered obsolete overnight, and new designs were brought forth once a year. The industry was in great need of stabilization. The permanence of broadcast transmission was uncertain, and some manufacturers became fearful of investing capital and producing radio apparatus under such uncertain conditions.

From 1922 on, hundreds of manufacturers engaged solely in the production of component parts for broadcast receivers for subsequent assembly on the part of the customer. It was estimated that, in 1924, there were about 3,000 manufacturers of parts for home assembly of broadcast receivers and 300 set manufacturers, most of whom were infringing patents owned by other interests. From the commercial viewpoint, this expansion was recognized as abnormal; the industry could not continue to support so many manufacturers of equipment. But the business of accessory manufacturers dwindled automatically after 1925, for the public no longer evinced marked interest in constructing receiving apparatus from parts and assemblies made here and there, and often not properly coördinated. The market trend was then in the direction of complete receiving sets enclosed in cabinets of the table type or floor type. Receiving apparatus embodying loud speaker and all accessory devices in a single cabinet grew in public favor. The public demand for the receiving sets shifted from the brand of one manufacturer to the other, and the manufacturer of the brand that declined in popularity was often faced with bankruptcy. By 1926, leading set manufacturers had been reduced in number to some 40 organizations, and the manufacturers of parts from several thousands to a few hundred.

Chaotic conditions in the field of marketing. In the field of distribution and sales, conditions were equally chaotic from 1922 on. The wholesaler and the retailer, regardless of whether they were conversant with the technicalities of the art or of the business they were engaged in, insisted upon being appointed as distributors of radio merchandise. Hence, we find the curious anomaly of radio receiving sets being sold by department stores, drugstores, hardware stores, clothiers, and others. Little forethought was given to the necessity of having highly specialized personnel for the installation and service of such equipment. Claims were made for performance of radio sets that could never be realized. The retail business was often in the hands of a type of merchant who took no responsibility after effecting a sale

Federal Radio Commission appointed. As 1927 approached, the air became cluttered with broadcast-transmitting stations. There were not enough frequencies or wave lengths in the radio spectrum available for all the applicants for broadcast-transmitting licenses The Department of Commerce was faced with a most difficult problem, and legislation was enacted in February, 1927, placing the assignment of wave lengths

for radio transmission in the authority of a new body, the Federal Radio Commission.

With all available channels for radio transmission taken up, the commission, through sheer technical necessity, placed a limit on the number of licenses granted. Its decisions from time to time resulted in some severely contested disputes between the applicants and the commission.

Necessity for financial support of broadcasting realized. In the early days of broadcast development, the services of the artists, musicians, and professional talent were secured free of charge in practically every instance. Many of these broadcast stations were erected by commercial interests primarily for institutional advertising and to develop public good will. Religious organizations, colleges, newspapers, and manufacturing companies—in fact, a wide variety of interests—found this new channel for entertaining the public a source of prestige and good will; but they were soon faced with a problem of magnitude, namely, that of obtaining revenue for the support of their daily programs. They had incurred an obligation which had not been maturely considered at the time when these stations were erected. The cost of installing and operating such stations was found to be very large. The day was foreseen when artists and entertainers would demand remuneration for these services; and from 1925 on, there was a growing fear throughout the radio industry that radio-broadcast entertainment, unless supported by some form of revenue, might collapse. Indeed, many of the broadcasters found these undertakings so expensive that they discontinued the operation of their stations. What the future held in store was problematic, and no immediate solution seemed in sight.

Development of radio advertising. It was found that a broadcasting station had advertising value of a peculiar nature in an entirely new field. As the problem of obtaining revenue for the operation of broadcasting stations was approaching its crisis, it found solution in a plan initiated by the American Telephone and Telegraph Company in its operation of station WEAF. The Telephone Company adopted a policy of selling "time on the air" through station WEAF to commercial organizations who had something to sell to the public. The advertising features of the program were limited to the announcement of the name of the manufacturer, the business the manufacturer was engaged in, or the merchandise he had to sell. The program was primarily and fundamentally one of varied, high-class entertainment. Subscribers to this entertainment quickly found that this form of advertising was remunerative, that it actually increased the sales of their products and their patronage throughout the nation.

Importance of wire-line interconnection—"network" broadcasting. In 1926, radio-broadcasting stations were not interconnected by land-line telephone wires except in the case of stations WCAP, in Washington, D. C., and WEAF, in New York, which were connected by the land lines of the American Telephone and Telegraph Company. By proper technical treatment, the wire lines would transmit speech and music without

the entertainment which the Columbia System provides to the American public is a distinct contribution to the broadcasting art.

International Broadcasting

Among the innovations in programs introduced by both the National Broadcasting Company and the Columbia Broadcasting System is the transmission of radio programs from the United States to foreign countries and vice versa. This work was begun several years ago, but it was only during 1931 that these feats achieved reasonable reliability. The programs are transmitted on what are termed "short waves"—that is, at very high frequencies. Usually, these transmissions take place on wave lengths between 16 and 75 meters. NBC is currently (1941) broadcasting international programs 16 hours a day, in English, Spanish, Portuguese, Italian, German, and French.

Importance of short-wave transmission. A detailed statement of the technical development of short-wave transmission for broadcasting and for the transmission of international radio-telegraph traffic would occupy too much space in this résumé. Suffice it to say that the Westinghouse Electric and Manufacturing Company was initially responsible for the eventual success of this development, having erected a short-wave broadcasting station at East Pittsburgh, Pennsylvania, in 1922, which simultaneously transmitted the broadcasts of its regular station, KDKA. The station was also equipped for radio telegraphy. Its programs and its telegraph signals were heard at times throughout the world. About the same time, Guglielmo Marconi engaged in experimentation in this field, having established a laboratory on his private yacht, where he had conducted such researches and tests in foreign waters. Both he and Westinghouse made notable contributions to short-wave development. The work of these two pioneers was supplemented by research and field tests of the General Electric Company and the Radio Corporation of America, resulting finally in a commercially practical system for international radio communication. After years of study and analysis of the phenomena of short-wave transmission, generally on the part of engineers, it was found that, by careful and unique design of the transmitting and receiving apparatus and by the selection of specific wave lengths at certain hours of the day, suitable to general atmospheric conditions, short waves permitted the transmission of intelligence over very great distances. Waves below, say, 40 meters were found more effective in daylight and waves from 40 to 100 meters more effective at night.

Overco[...] obstacles in international broadcasting. One of the
-wave transmission is the phenomenon of "fading,"
nt in this section of the radio spectrum than in others.
the Radio Corporation of America have been able
eliable service by means of multiple-receiving sta-
ceived at two or more points simultaneously, it
that, when the short-wave signal at a given receiv-
imum, it may be at a maximum at another station

near by or at some intervening value at still another station. Hence, by the erection of a group of such receiving stations and by the combination of their outputs, it is possible to secure a transoceanic radiotelephone signal of moderately uniform intensity. It is through this development that the international exchange of radio programs has been accomplished. Much remains to be done, however, to give a service equal to that rendered by local stations.

International Radio-Telegraph Communication

Appreciation of the great strides that have been made in radio telegraph communication is not nearly so universal as the public familiarity with broadcasting. This is perhaps only natural, since the business of handling messages by radio from continent to continent does not have an intimate contact with the home, as does broadcasting. Some of the more important developments in this field, leading approximately to the year 1920, have already received mention here. Experimental endeavors to establish communication with foreign countries prior to 1919 have also been described, it being pointed out that the United States stations existing at the time this country entered the First World War were employed by the Government.

On February 29, 1920, the Government relinquished control of the stations which it had taken into custody upon the declaration of war. On that date, it turned over to the Radio Corporation of America the stations formerly owned by the Marconi Wireless Telegraph Company of America.

The Radio Corporation had already made plans for rehabilitating these stations with the Alexanderson high-frequency alternator system. Its first installations were made at New Brunswick, N. J., Bolinas, Calif., Marion, Mass., Kahuku, in the Hawaiian Islands, and later at the Tuckerton, N. J., station.

One of the important improvements developed by engineers of the RCA group which did much to establish the early success of international radio communication was the so-called "wave antenna," a new principle in radio reception which, for the first time, effectively reduced atmospheric electricity commonly known as "static." This new development, coupled with vacuum tubes and heterodyne reception, provided more uniform and more reliable reception from European stations than did any other prior invention known to the art.

Establishment of the Transoceanic Communication Circuits

In the first year of its existence, 1920, the Radio Corporation inaugurated the following transoceanic radio circuits:

New York to Great Britain	March 1
San Francisco to Hawaii	March 1
Hawaii to Japan	March 1
San Francisco to Japan	March 1
New York to Norway	May 17
New York to Berlin, Germany	August 1
New York to France	December 14

These new services were made possible by traffic agreements that had been executed between the Radio Corporation of America and foreign interests, either with the Government bureau in control of international communications in a given country or with private corporations

On November 5, 1921, RCA completed the construction of the Rocky Point, Long Island, station, which was officially opened by President Harding. This was the world's largest international radio-telegraph station, equipped with an antenna system approximately 12,000 feet in length and with 200-kw. high-frequency alternators. In that same year, a 200-kw. Alexanderson-alternator system was installed at Tuckerton, New Jersey.

By reason of the operating freedom gained through an exchange of patent licenses, substantial and effective improvements were made in transmitting and receiving apparatus, so that, in these first attempts, a practical international radio service could be rendered. One of the first results of this new competition in the field of international message traffic was a substantial reduction in message rates, the charges established by RCA causing the cable companies to reduce their traffic charges to certain foreign countries for the first time in a period of 38 years.

Short-Wave International Radio-Telegraph Communication

Experiments with short-wave transmission. At the time the installation of the high-frequency alternator systems was undertaken by the Radio Corporation, General Electric Company, Westinghouse Electric and Manufacturing Company, and also Senatore Marconi were experimenting with so-called "short-wave" transmission—that is, in the region of wave lengths below 100 meters. These waves constituted a distinct contrast to the wave lengths employed in the use of high-frequency alternators and arc transmitters, which were between 8,000 and 25,000 meters.

Short waves prove practical for long-distance communication. It was generally believed, prior to the years 1923 and 1924, that short waves had no practical value for long-distance communication; consequently, a large part of this wave band was delegated by the Department of Commerce to radio amateurs. But experiments of Westinghouse, General Electric, and the Radio Corporation demonstrated that wave lengths under 100 meters had a very real practical value in international communication. As early as September 11, 1924, the engineers of RCA and its associated manufacturing companies constructed experimental high-power vacuum-tube transmitters which successfully handled transoceanic radio traffic between New York and England, and New York and Germany. Simultaneously, the American Telephone and Telegraph Company obtained satisfactory results in establishing two-way telephony between ships at sea and its land-line telephone system, demonstrating also that radio telegraphy and radio telephony could be conducted simultaneously. In the early part of 1923, engineers of the American Telephone and Telegraph Company and of the RCA demonstrated that a high-power, long-distance vacuum-tube transmitter could be connected

to land-line telephone systems for long-distance radio telephony. Fessenden, however, was the pioneer in this development, having demonstrated the practicability of such a system in 1907. The Telephone Company prosecuted this development, until finally it perfected an international radio-telephone service.

Continued experience in the short-wave field demonstrated that transmission in this band was attended by extraordinary phenomena, and that, although such signals often could not be detected at distances of a few miles or a few hundred miles from a transmitting station, they could be plainly distinguished at distances several thousand miles from the transmitter. With further experience, it was noted that wave lengths from 40 meters up to, say, 100 meters were useful in short-wave communication during hours when both the transmitting and receiving stations were located in total darkness and that waves in the neighborhood of 25 to 35 meters were effective when the transmitter was located in the daylight zone and the receiver in darkness or vice versa. Wave lengths below 20 meters were found the most effective when both the transmitting and receiving stations were located in the daylight zone.

Problems in designing transmitters. Engineers encountered some difficult problems in the design of short-wave transmitters. A particular vacuum tube suitable for transmission at relatively long wave lengths was unsuited to the higher frequencies used in short-wave transmission. There was also the problem of securing efficient radiation from such transmitters. It required years of experimentation and testing and the expenditure of considerable sums of money to cope with these problems, but, by 1927, enough had been accomplished, experimentally and practically, to demonstrate that technical practices in international radio communication were at the turning point—so much so that there appeared to be no necessity of installing additional high-frequency alternators for expansion of these services.

Problem of fading solved—the diversity system. Short-wave transmission is, as we have said, accompanied by the phenomenon of fading. This, however, is a characteristic of all short-wave radio transmitters when one endeavors to establish communication beyond the daylight range of a given station. It was noted early that the extent of fading at a given moment varied with the transmitting wave length, and often when signals faded violently or disappeared completely on one wave length, communication could be reëstablished at another near-by wave length. Constant experimentation with this method of transmission also disclosed that, although a signal might fade out at a given receiving station, it would be of maximum intensity at another station less than 1,000 feet away. Noting these phenomena, engineers of the Radio Corporation devised, in 1928, the so-called "diversity system" for radiotelegraph and telephone reception, which, in its practical form, consists of three receiving stations located 600 to 1,000 feet apart, the signal outputs of the stations being connected in common. Thus, through the use of appropriate "volume-level" devices, there is usually sufficient signal energy in one or another of the receivers to give an acceptable

signal in the final output stage. This new system has proved to be the most effective method of coping with this problem, for it has made international radio-telegraph communication by short waves continuous and reliable. It is now usual at short-wave commercial stations to receive simultaneously on a single short-wave antenna system from five to seven telegraph messages from different parts of the world.

Dealing with the situation from 1928 on, we find that the preponderance of international radio-telegraph traffic from this country is handled by short-wave transmitters which, with outputs of 20 kilowatts to 40 kilowatts, are able to render service over tremendous distances at phenomenal speeds of operation.

International radio-traffic circuits. It should be noted, however, that the short-wave transmitter has not completely displaced the high-frequency alternator. Even at this date, the original 200-kw. alternators installed by RCA at Marion, Mass., New Brunswick and Tuckerton, N. J., and Rocky Point, N. Y., are dispatching traffic to Europe, to countries not equipped for short-wave operation. It is also of interest to note that one of the large antenna systems at Rocky Point is used by the American Telephone and Telegraph Company for international radio telephony at the longer wave lengths.

The Rocky Point installation has more than 30 short-wave transmitters for direct contact with various parts of the world.

The international traffic circuits, cited above, established by RCA, were expanded in subsequent years by the following additional circuits:

New York to Italy	August 10, 1923
New York to Poland	October 4, 1923
New York to Argentina	January 25, 1924
New York to Sweden	December 1, 1924
San Francisco to Netherlands India	July 16, 1925
New York to Brazil	May 3, 1926
San Francisco to French Indo-China	September 15, 1926
New York to Holland	November 1, 1926
New York to Netherlands West Indies (St. Martin)	June 21, 1927
San Francisco to Philippine Islands	June 27, 1927
Hawaii to Philippine Islands	July 1, 1927
New York to Surinam	August 9, 1927
New York to Colombia	August 12, 1927
New York to Venezuela	August 18, 1927
New York to Belgium	October 3, 1927
New York to Puerto Rico	October 10, 1927
San Francisco to Hong Kong (via Philippines)	July 23, 1927
San Francisco to Shanghai, China	December 6, 1930
New York to Turkey	December 10, 1927
New York to Montreal, Canada	March 10, 1928
New York to Portugal	April 2, 1928
New York to Australia (via Montreal)	June 15, 1928
New York to Curaçao, Netherlands West Indies	August 4, 1928
New York to Liberia	September 1, 1928
New York to Cuba	December 4, 1928
Hawaii to Fiji Islands	May 1, 1929
New York to Spain	August 1, 1929
Puerto Rico to New Orleans	August 12, 1929
New York to Syria	September 3, 1929

New York to Santiago, Chile.	January 13, 1930
New York to Panama	May 1, 1930
New York to U.S.S.R.	November 13, 1930
New York to Czechoslovakia	December 1, 1930
New York to Dominican Republic	December 24, 1930
San Francisco to Changchun	June 9, 1931
New York to Mexico	March 15, 1932
New York to Switzerland	May 11, 1932
New York to Haiti	July 1, 1932
New York to Guatemala	January 22, 1934
Honolulu to Tahiti	September 1, 1934
New York to Iceland	January 1, 1938
San Francisco to Chengtu, China	July 30, 1938
New York to Greenland	April 25, 1940

The list is impressive. It indicates that a large number of international traffic circuits are available to American industry engaged in export trade, to our diplomatic and consular services, and to the public in general—and without the censorship of intervening nations in times of war or peace.

Development of a facsimile service. As early as 1924, the Radio Corporation had developed a facsimile service by which printed and written documents or photographs could be dispatched across the Atlantic Ocean. The service has undergone extensive improvement. The possibility exists that future progress will enable this method of telegraph transmission to be used exclusively. Its value in transmitting legal documents, certified copies of contracts, and even bank checks is obvious

International radio-telephone service. The present international radio-telephone service developed by the American Telephone and Telegraph Company is another outcome of the many inventions made in the radio art and of the progressive research conducted by its engineers. Provision of a workable transoceanic telephone system involved the overcoming of more serious technical obstacles than those initially encountered in the field of radio telegraphy. However, with the degree of perfection that has now been attained, it is possible for the telephone user in any part of the United States to establish direct telephone communication with any other subscriber in England and the greater part of continental Europe. A similar service is rendered to points in South America. Indeed, the principal countries of the world are now connected by radio telephone through services established by interests abroad as well as those established by the American Telephone and Telegraph Company in the United States.

RCA Extends Licenses to Outside Radio Manufacturers

Patent litigation. Widespread infringement of the patents owned by RCA or under which it obtained licenses from the original owner led to extensive patent litigation in the period 1921 to 1927, and several court decisions were handed down in which the validity of certain of the basic radio patents was established.

Some of the more responsible firms then engaged in the manufacture

of infringing radio-broadcast receivers became more and more alarmed about the hazards of the business, foreseeing that, sooner or later, patent rights must be respected and that, if they continued to do business on such unsound grounds, they would face disaster. The Radio Corporation, on the other hand, saw that it could cope with the nation-wide infringement of its patent rights only by the expenditure of large sums of money, time, and energy, and that success in suppressing infringers would result in much ill-will. It appeared to the Radio Corporation that the interests of all concerned could best be served by granting licenses to the manufacturers whose sets had gained public acceptance and who were financially sound and capable of serving the public.

Licenses granted to manufacturers. Broadcast-receiver licenses were originally granted only for what were termed "tuned radio-frequency receivers." However, in 1930, the licenses were extended in scope to include all kinds of radio-telephone broadcast receivers, such as superheterodyne receivers, which have nearly completely superseded and outmoded tuned radio-frequency receivers; and also receivers of broadcast moving and still pictures, known as "television" and "facsimile receivers," electric phonographs, and talking moving-picture reproducers for use in homes. Therefore, the broadcast-receiver licenses granted by RCA have long included all kinds of "home" apparatus utilizing radio circuits for which there is a real or potential demand by the general public.

One of the first manufacturers to take advantage of such an arrangement was the Zenith Radio Corporation of Chicago, which, for years prior to 1927, had operated a broadcasting station and manufactured broadcast receivers utilizing circuit and vacuum-tube patents of the Radio Corporation and its manufacturing associates. Subsequently, a number of other manufacturers took licenses, so that, by November, 1927, licenses had been granted by the Radio Corporation to 25 manufacturers of radio-broadcast receivers. These license agreements contained no restrictions as to the number of sets to be manufactured by the licensee or the price at which they were to be sold. Thus, licensed competition in the radio-broadcast field was in no wise restricted.

Licenses afford extraordinary advantages. Emphasis should be laid on the extraordinary facilities which these licenses afforded to these manufacturers. For example, if the research departments of the Radio Corporation of America, General Electric Company, Westinghouse Electric and Manufacturing Company, Western Electric Company, and American Telephone and Telegraph Company originated new developments in the tuned radio-frequency field, the right to use such inventions immediately passed to the licensee. The cost of the combined research of all these companies in the radio field has amounted to many millions of dollars, and the practical results of these expenditures flow to the licensed manufacturers without cost, other than the royalty charges.

The Radio Corporation also acquired many outside patents needed in order to manufacture and sell the most efficient types of radio apparatus free from infringement. If the rights so obtained permitted the Radio

Corporation to extend licenses to the others, the set licensees automatically obtained rights in their fields under these patents.

It should be noted here that the cross-licensing agreements effected between the Radio Corporation group and its cross-licensing associates did not include all of the patents in the radio field; nor did it wholly free a manufacturer from the possibility of infringement. Many radio-patent rights are held by other interests, some of which have also licensed RCA's licensees.

Chaotic condition developed in vacuum-tube fields. A chaotic condition developed in the manufacture and sale of vacuum tubes. The important and basic patents resulted from inventions made or acquired by the members of what we shall, for convenience, call the "RCA group," but a number of manufacturers engaged in the production of vacuum tubes without regard to existing patents. At one time, 100 or more companies were producing tubes; and the product of some of these manufacturers was sold to the public, often at prices that did not take into account the cost of production. As a result, there were many failures, although new companies sprang up to take their places.

Licenses granted to tube manufacturers. This situation promised a confusion like that which had existed in the radio-set field. Again, it seemed imperative to eliminate the great difficulties of this phase of the radio business. To this end, the Radio Corporation, in 1929, granted licenses under all of its vacuum-tube patents to a number of tube manufacturers.

Outline of RCA's licensing rights. The fields and apparatus for which RCA has in general the right to grant licenses to others under the patents of the American Telephone and Telegraph Company, in addition to its own patents and those of General Electric and Westinghouse, are as follows:

(1) Wireless telephony:
- (*a*) For one-way wireless reception of programs.
- (*b*) For amateur wireless telephony.
- (*c*) For two-way transoceanic apparatus for export from the continental United States

(2) Wireless telegraphy (including facsimile and television):
- (*a*) For all purposes including public-service communication, except combined telephone and telegraph sets for use on ships

(3) Wire telephony:
- (*a*) For the reception of programs over wires and other conductors.
- (*b*) For the one-way transmission and reception of programs over electric-light, heat, power, and traction lines.
- (*c*) For carrier-current communication over electric-light, heat, power, and traction lines only for the use of the owner or operator of such lines.

(4) Wire telegraphy:
- (*a*) For transmission and reception of programs over electric-light, heat, power, and traction lines

(5) Electrical phonographs for use in homes and for use in combination with radio-broadcast receivers or with apparatus for the transmission and reception of programs over electric-light, heat, power, and traction lines.

(6) Electrical apparatus for the production in homes of sound records and for such records themselves (for private use and not for sale), and for such apparatus in combination with radio-broadcast receivers or with apparatus in the field of one-way wire telephony for the transmission and reception of programs over electric-light, heat, power, and traction lines

(7) Apparatus for the taking or projection of pictures, apparatus for coordinating such taking or projection in relation to the recording or reproduction of sound records, and such sound and picture records themselves only for private use in homes for entertainment and educational purposes

(8) Methods and processes for the recording of sound and the production of sound records, and the reproduction of sound from records in connection with the use of apparatus for which RCA is otherwise licensed

(9) Radio goniometry.

In addition to the foregoing, RCA has the right to grant licenses to others under the patents of General Electric and Westinghouse, as well as its own, but not under the patents of the American Telephone and Telegraph Company, in general, for all other fields of wireless telephony and wireless telegraphy than the foregoing, for certain fields of wire telephony and wire telegraphy, for most uses of electric phonography, for the recording of sound and pictures and the reproduction thereof from records, and for sound-originating apparatus.

Licenses Granted to Broadcasting Transmitters

Several hundred broadcasting stations were erected by various interests in the United States between 1921 and 1927, quite regardless of the ownership of patents pertaining to such equipment. Noting this nation-wide infringement of its patent rights and licenses under patents, the American Telephone and Telegraph Company took action in defense thereof, instituting a few infringement suits, one of which was against a station located in New York City After due consideration of the circumstances existing in the industry, the American Telephone and Telegraph Company inaugurated a licensing policy under which the infringing stations could continue to operate and could also secure the Telephone Company's wire-line facilities for station interconnection. The attitude of the American Telephone and Telegraph Company was another instance in which the solution permitted a group of conflicting patents to be used for the public benefit.

Unwarranted criticism of license agreements. Uninformed critics, perhaps without knowledge of the peculiar set of circumstances that attended the growth of the radio industry in this country, have been prone to treat the interchange of licenses as a premeditated plan of a group of industries to attain unwarranted control of the radio business They do not understand that cross-licensing was a sheer technical necessity born of the limitations of the art. What actually happened was that this group resolved the most chaotic patent situation that has ever existed in any industry into a situation where the benefits of all of the patents accrued to the public good, permitting the lawful manufacture and sale of devices embodying all the efficiency of operation and refine-

ment of which the art was technically capable. The licensing policy of the Radio Corporation and its associates has had the effect of encouraging very great competition in the radio industry.

Probable results without license agreement. Let us consider for a moment the conditions that probably would have obtained had not the great organizations concerned exchanged patent licenses. The industry would then have labored under the handicaps of conflicting patents with overlapping claims. Each company would have been compelled to pay tribute to some other company or patentee—not to one or two patent owners, but to a large number. The license fees which these many individual patentees could have justly demanded individually would, in the aggregate, have been so great in themselves as to prevent the development of satisfactory radio devices and the practical manufacture and sale of these devices. Indeed, the development of the art would have been retarded and the American public would not, at this date, have the advantages and benefits which it now derives from an organized broadcast service, a world-wide radio telegraph and telephone service, improved recording and reproduction of speech and music, talking pictures, and the numerous other devices born in the radio field.

Research and Development

During 1939, the major emphasis of the advanced work of RCA Laboratories was upon developments in the ultra-high frequency field. Out of these investigations have come entirely new types of vacuum tubes for producing power and for amplifying and detecting radio signals over the vast new range of frequencies extending from 30,000 to 1,000,000 kilocycles. These higher frequencies are useful in nearly all fields of radio communication—telegraphy, telephony, sound broadcasting, facsimile, television, and marine, aviation, and police services.

Three new services now beckon those who seek to expand radio's usefulness They are: radio facsimile, frequency modulation, and television.

Radio facsimile. Radio facsimile is the transmission of pictures and printed matter through the air. It is now bringing photographs from many parts of the world for prompt use in daily newspapers. Its development may include services for the home, as well as for the press.

Frequency modulation. Frequency modulation (F.M.) holds much promise for the future. Its growth in broadcasting services will probably be gradual. Only time can determine the extent of its full development.

RCA's research engineers have done pioneering work in this field and in the development of uses for the ultra-high frequency spectrum, where F.M. has its most advantageous applications. Laboratory tests and field experiments have been extensive. Many fundamental inventions have been made during the course of this work.

F.M. represents an important forward step in the broadcasting of sound. The Federal Communications Commission authorized frequency

modulation on a commercial basis on May 20, 1940, and established procedure on June 29 of the same year.

Television. Television, on the other hand, adds sight to sound and stands today on the threshold of public service. In time, it is bound to

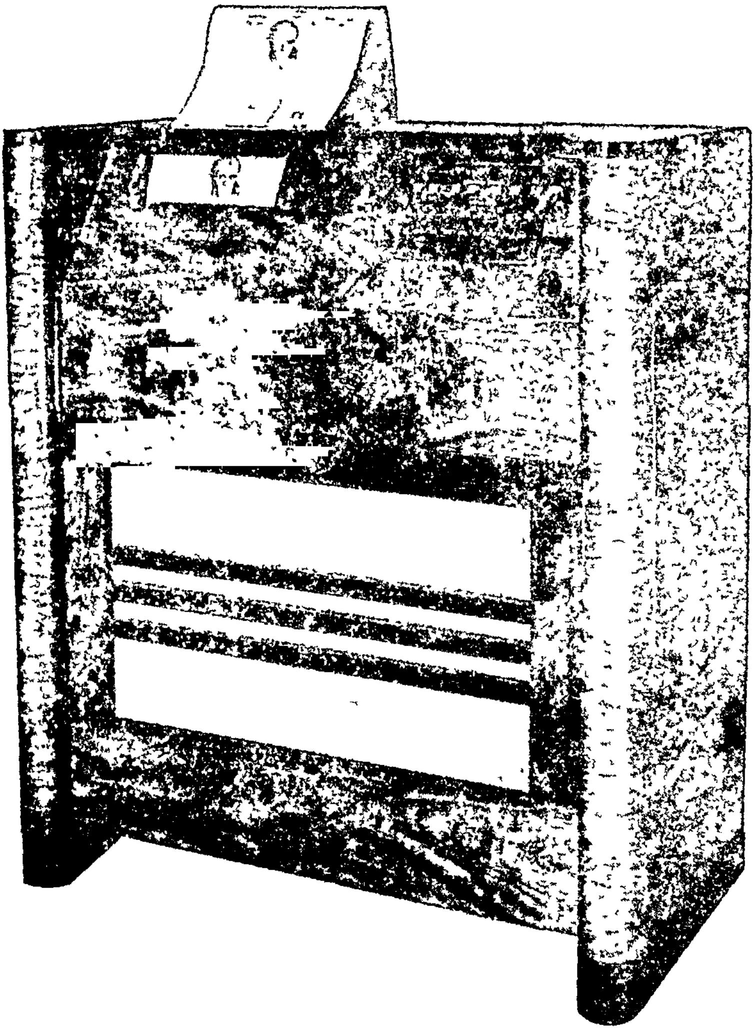
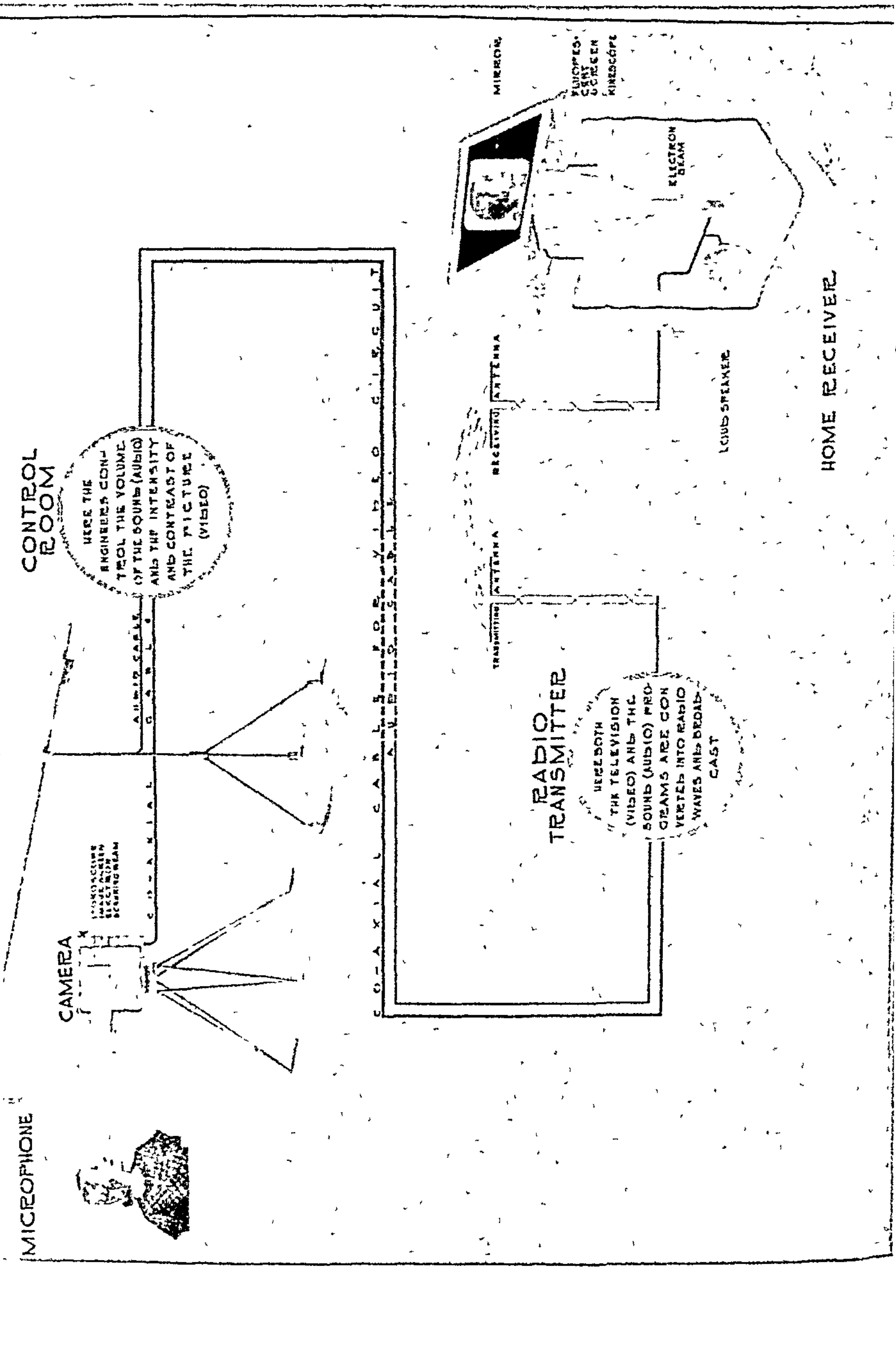


Fig 1. Model of an RCA radio-facsimile receiver

revolutionize the broadcasting industry just as the addition of sound to sight revolutionized the motion-picture industry.

While television will provide a new service for the home, it will be useful also in theaters and other public places No one can foresee all the future uses to which it may ultimately be put, but this much is



MICROPHONE
CAMERA
CONTROL ROOM
HERE THE ENGINEERS CONTROL THE VOLUME OF THE SOUND (AUDIO) AND THE INTENSITY AND CONTRAST OF THE PICTURE (VIDEO)
AUDIO CABLE
COAXIAL CABLE
COAXIAL CABLE FOR VIDEO CIRCUIT
RADIO TRANSMITTER
HERE BOTH THE TELEVISION (VIDEO) AND THE SOUND (AUDIO) PROGRAMS ARE CONVERTED INTO RADIO WAVES AND BROADCAST
TRANSMITTING ANTENNA
RECEIVING ANTENNA
MIRROR
ELECTRON BEAM
LOUDSPEAKER
HOME RECEIVER

clear: the addition of sight to sound in radio will be of vital importance to industry, education, and entertainment.

The quality of television images broadcast by NBC has shown steady improvement in brilliance and clarity. A new type of Iconoscope, or pick-up tube—the "Orthicon"—was developed by RCA Laboratories and tested with great success by NBC. This type of Iconoscope, far more

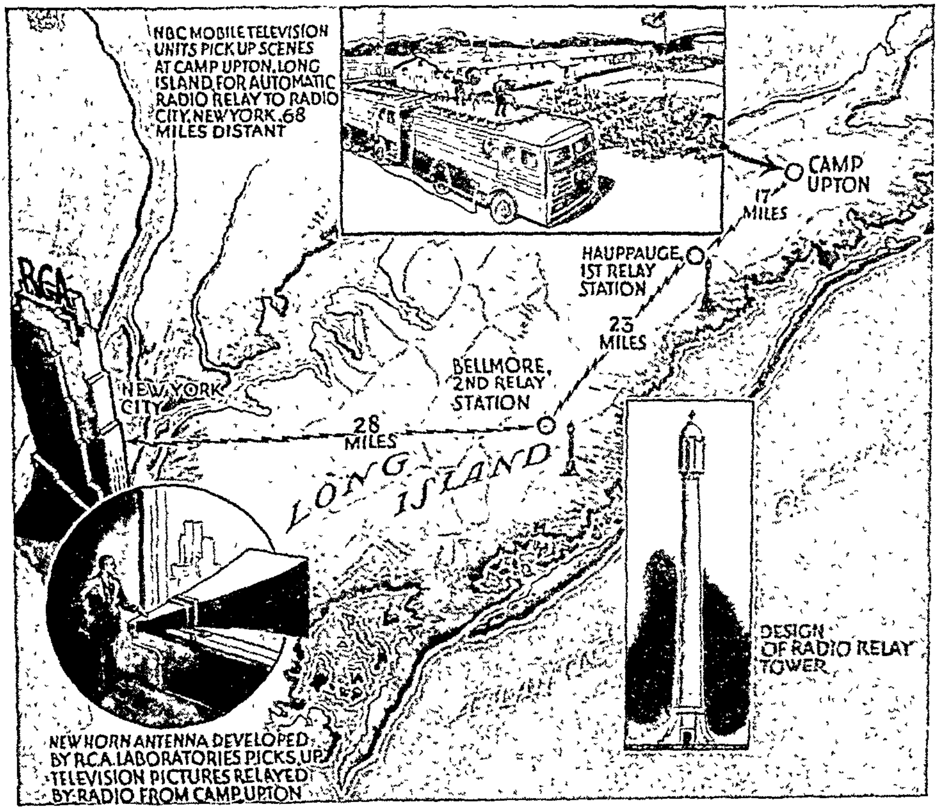


Fig. 3. A new radio relay system By means of this system, television pictures can be transmitted between widely separated cities It was demonstrated recently by the Radio Corporation of America for members of the Federal Communications Commission. The system, developed by RCA Laboratories, works automatically. It makes possible the establishment of intercity television networks similar in effect to those used in sound broadcasting.

sensitive than any heretofore employed and requiring less brilliant light on the subjects televised, was made available to all television stations during 1940. Similarly, the latest types of television transmitters developed by RCA are available to all stations, through the RCA Manufacturing Company. RCA has licensed competing manufacturers, in consideration of royalty payments, to make and sell such transmitters, as well as television receivers.

Two important new television developments are now technically ready for public service. One is a system of television-radio relays, different from any other system so far devised, which offsets the distance limitations of ultra-short waves. This new RCA system makes possible the establishment of intercity television networks comparable to the wire networks of sound broadcasting. This development makes it feasible to

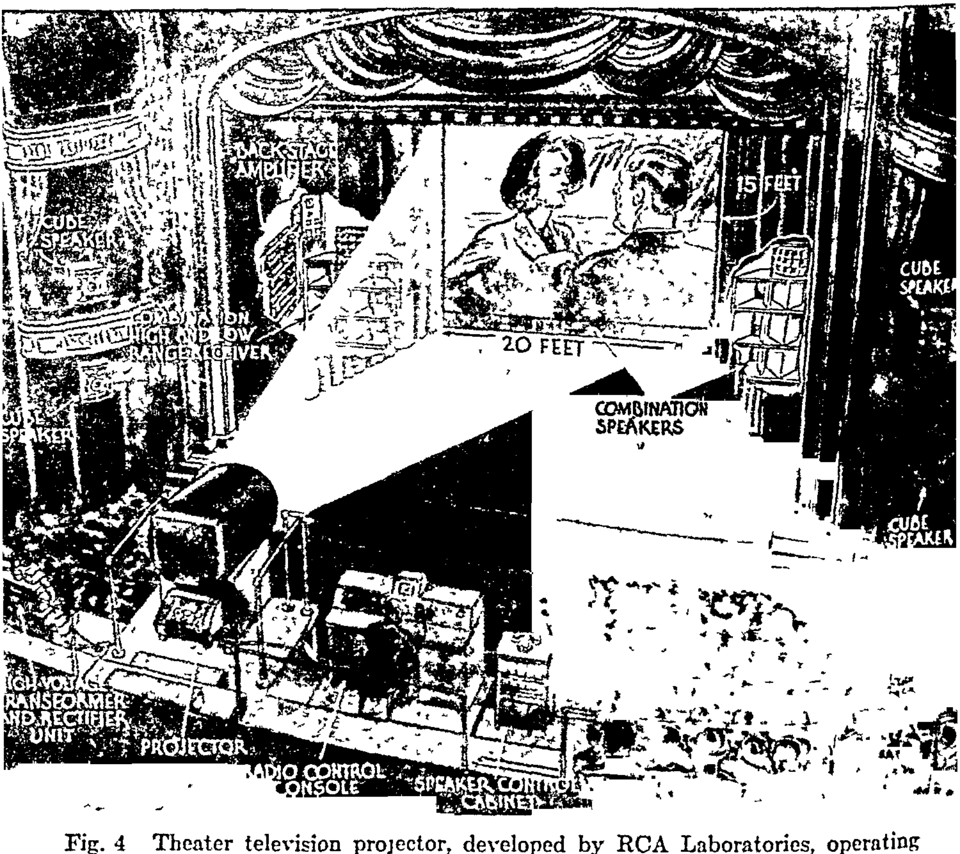


Fig. 4 Theater television projector, developed by RCA Laboratories, operating in conjunction with a multisonic sound system, as demonstrated at the New Yorker Theater for the Federal Communications Commission and National Television System Committee. The telepictures, 15 by 20 feet, are projected onto a screen located on the stage 60 feet from the steel-jacketed projector. The operators at the control desks regulate the focus, brilliancy, and sound volume of the picture. Eighteen high- and low-frequency loudspeaker systems scattered throughout the theater are used in the multisonic arrangement.

set up a radio-relay system for television linking New York City, for example, with Washington, D. C., and with Boston and other intermediate cities.

The other new television development is the improved projection of large-screen television images, of a size and clarity suitable for theater presentation. Large-screen television will permit the showing of current

events and other programs to large audiences. The relay system described above offers a practical means for distributing television programs to theaters, whether in a single locality or in the several cities of a television network.

Television offers new opportunities for the employment of men and money, for the expansion of entertainment and other services, and for the creation of a new medium of advertising for American industry and business.

37

The Retailing Industry

Introduction

About 5,500,000 people in the United States, or about 1 out of every 25, are directly engaged in the retail industry. The more than 1,600,000 stores paid their full-time and part-time employees nearly $4,000,000,000 in salaries and wages in 1935.

Hundreds of thousands of employees in stores intend to work only temporarily, earning a few dollars for some special purpose they have in mind and then resigning. Labor turnover is enormous.

Enterprising novices by the thousands place their savings from other sources in a stock of goods and open a store. Lack of capital and inexperience are their doom. Every year one third of the grocery stores, one fourth of the shoe stores, and one fifth of the drugstores withdraw from business. This high rate of retail mortality is the result of the belief that anyone can operate a store.

It is a common belief that retailing is inseparably connected with running a store. This is not true. The Jewel Tea Company, for example, has no stores; the Fuller Brush Company, a leader in its line, is a storeless retailer; and Sears Roebuck and Montgomery Ward, until recently, sold hundreds of millions of dollars of merchandise each year without operating stores. But if all retailers could sell merchandise without maintaining stores, countless retailing problems would be solved, only to have new ones take their place. Nevertheless, a store symbolizes modern retailing, and the history of stores can be traced to antiquity. Recently, an ancient store, which had two floors with outside stairs leading to the second floor, was excavated in Greece.

Records indicate that the first commercial trading (3000 B.C.) was carried on throughout the Mediterranean region by the Minoans or Aegeans and that control of trade was successively held by the Phoenicians, Greeks, Romans, and Europeans.[1] The first traders were adventurers, and it is not surprising that their barter was frequently accompanied by fraud and violence. Mercury, the god of cunning and trickery, was

[1] Nystrom, Paul H., *The Economics of Retailing* (New York: The Ronald Press Company, 1930), Vol I.

chosen the patron deity of merchants. Retailer in Greek means the same as falsifier. The old Italian word for retailer also meant "the tendency to cheat."[2]

History of Retailing in the United States

Before the outbreak of the Civil War, four types of retail outlets were predominant in the United States: (1) markets and fairs; (2) peddlers; (3) general stores; and (4) specialty stores.

Public markets. Since fairs and markets were the chief centers of commerce in Europe during the Middle Ages and were of major importance in trade of the sixteenth and early seventeenth centuries, the colonists brought to America the idea of establishing public markets. In 1658, Boston, followed by other leading cities, erected a building for a market. These public markets were wholesale in nature and are considered the forerunners of the organized produce exchanges, such as the coffee, sugar, or cotton exchanges in New York and other commercial centers. Retail public markets were important, until the last quarter of the eighteenth century, as places where products from different localities could be exchanged. Their importance tended to decline with the growth of stores.

The fairs. Contrasted with the market, which was local in scope, was the fair, which was attended by buyers coming from considerable distances. Fairs, held only at infrequent intervals, were primarily exhibitions instead of markets. The fact that the entertainment features overshadowed the selling activities of exhibitioners is one of the causes for the decline of the fair as a retail outlet.

Early peddlers. The itinerant merchant or peddler bought his goods from factories and importers and at markets, auction places, and fairs. He sold them to people in their homes, often bartering with them for goods which they could not dispose of to advantage at the market places or fairs. There were many types of peddlers—the general peddler, who hawked pins, needles, books, combs, small hardware, cotton goods, and laces; the one-line peddler, such as the tin peddler, clock peddler, or woodenware peddler, who developed with the beginning of the manufacturing industries in New England; the wholesale peddler, who supplied the local merchants with goods; the waterway peddlers; and other wayfarers, such as wandering craftsmen and professional men.

The early peddlers, mainly New Englanders who were deprived of employment opportunities at home, were an adventurous type, able to cope with the dangers of long and lonely stretches of wilderness between customers. As roads became more general and safer, peddling slipped into the hands of the older men who were incompetent for other work. The introduction of the factory system in New England eased the economic situation and opened opportunities for young men who had previously been Yankee peddlers. Many of the recent Jewish immigrants

[2] Brisco, Norris A., and Wingate, John W., *Retail Buying* (New York: Prentice-Hall, Inc., 1931).

started peddling, but as soon as they saved enough from their peddling activities, they set up stores. Several great stores had their genesis in this manner.

Origin of the general store. The general store originated as an outgrowth of trading posts. The trading post of the frontier supplied such goods as could not be produced by the pioneers themselves. In nearly every community, the first store formerly was a trading post, where furs were purchased from Indians or trappers and goods given in exchange. As the pioneers became established in their new homes, their wants increased in scope. Hence, the trading post was transformed into a general store handling dry goods, hardware, groceries, and drugs. The general-store merchant usually visited the wholesale centers twice a year, buying enough to last until the next trip. Fill-in goods were obtained from the wholesale peddlers.

The retail price of goods was determined by the bargaining ability of the customer. Usually, only the cost prices were marked on the goods, and a sale was often an extended and heated debate between customer and clerk. Advertising was mainly by word of mouth, the only printed advertising being statements that the merchant was conducting a general store. Owing to the lack of money as exchange media before the War of 1812, trades were conducted mostly by barter. Farmers who sold their goods to the merchant were given orders on the store for the value of the goods. These orders could be used in paying for subsequent purchases made at the store. Collections on credit accounts were slow, as settlements were generally made annually. The social standing of retailers was decidedly low; they were not even favored by the title of "merchant." The shopkeeper's, or shopmonger's, low standing resulted from his inefficient and often dishonest methods, which left a bad impression upon the community. It was the general belief that the customer was always the victim.

Development of the specialty store. With the growth of a community, there arose a demand for a variety of goods in each line greater than the general store offered. The one-line independent, or specialty store, supplied this need. The specialty store developed first in the larger cities and gradually spread to the smaller centers as soon as they could support a grocery, hardware store, dry-goods store, or drugstore.

Development of the department store. There is contradictory evidence as to the forerunner of the department store. Although some of the department stores were outgrowths of general stores, the evidence seems to point to the conclusion that department stores originated from dry-goods stores. R. H. Macy and Company, in New York, was founded in 1858 as a fancy-goods store; Wanamaker's, in Philadelphia, opened in 1861 as a men's clothing store; Jordan Marsh Company, in Boston, was founded in 1851 as a dry-goods jobbing house; Gladding Dry Goods Company, in Providence, Rhode Island, was a dry-goods store in 1866; and Lord and Taylor, in New York City, opened a dry-goods store in 1826.

It is generally accepted that the first department stores arose in

France, where the Bon Marché and the Louvre were established in 1852. In America, many stores claim to have been the first. Although there is no certainty as to which one was the very first to be established as a department store, Jordan Marsh of Boston, Hager and Brothers of Lancaster, Pennsylvania, Wanamaker's of Philadelphia, R. H. Macy and Company of New York, A. T. Stewart of New York, and the Zion Co-operative Mercantile Institute of Salt Lake City were among the first.

Owing to the falling price levels following the Civil War, the narrowing margin of profit, the tightening of long-time commercial credit, the increasing demand of the public for variety in goods, and the growth of population, particularly in the cities, economic conditions were favorable to the appearance of a new type of retailing, namely, the department store. A one-price policy, the use of advertising, the granting of multiple services, liberal returns, convenient locations, and large assortments of merchandise accounted for the early success of the department store, in spite of the agitation of small retailers, the misgivings of some customers, and the antidepartment-store legislation which was passed in a few states. Department stores enjoyed a tremendous rate of growth during the first 10 years of the twentieth century.

Development of mail-order retailing. Mail-order retailing dates from the establishment of Montgomery Ward and Company, in 1872. As many unprogressive small retailers continued the policy of giving the customers what was in stock, rather than trying to supply them with the things they asked for, customers began looking to other sources for their merchandise. The mail-order house was the source. Their variety of goods, low prices, liberal return policy, guarantees, and accurate descriptions in their catalogues appealed to many customers. Mail-order houses enjoyed their greatest prosperity between 1910 and 1920. Since 1920, the automobile, the increased importance of style, and the difficulty of adjusting prices to meet market conditions when catalogues are in the hands of the public have, in part, accounted for the decline of the mail-order business. The falling off in mail-order business has, however, been counteracted by the establishing of retail stores. At present, the sales of the leading houses are about equally divided between mail-order sales and retail-store sales.

Development of chain stores. The first chain store was the Great Atlantic and Pacific Tea Company, established in 1859. Most chains started from a single store. Since units were usually added only through the reinvestment of the profit, their growth was necessarily slow. None of the early chains started with the definite idea of becoming national or even sectional. The war and postwar period of 1916 to 1930 was a period of rapid expansion of the chain-store idea. The fashion of mergers, consolidations, and combinations of all kinds was especially adaptable to chain stores. Chain grocery outlets increased from 8,000 in 1914 to 63,000 in 1930. Chains, by limiting their stocks to standard fast-selling items, by attractive arrangement, good locations, efficient buying methods, and standardized operation, have applied the principles of scientific merchandising.

During the depression years of 1932 to 1936, chains were favored by customers who were forced by economic circumstances to buy as cheaply as possible. Chains obtained about one fourth of all the retail business. But by 1940, the chain-store growth was checked, at least temporarily. Many states began imposing chain-store taxes, chiefly of the graduated type whereby the tax per store increases with the size of the chain. Other adverse state legislation was passed, such as Fair Trade Acts, which permit manufacturers to practice price maintenance, and Unfair Practice Acts, which curtail "loss-leader" merchandising. The Federal Robinson-Patman Act restricts the quantity discounts available to large buyers such as chains. To counteract adverse legislation, chains have been replacing numerous small stores with a smaller number of larger stores. This reduces their tax, which is based on the number of stores operated. In the case of grocery chains, these new large stores have often been of the supermarket type.

Other recent developments. The tremendous recent growth of supermarkets may be reaching its peak. Legislation which caused, in part, chains to establish supermarkets is not increasing at its former rate. In many communities, the number of supermarkets has increased to the saturation point, and the keen competition between them is causing some of them to fail.

There is some evidence that the so-called "superettes," or miniature supermarkets, in neighborhood locations are potentially important as retail outlets. Consumer coöperatives are not important as far as their present sales volume is concerned; however, their rate of growth has been quite impressive in recent years. Because of population movements to suburban locations, many centrally located stores are establishing branches in suburbs. Voluntary chains composed of independent retailers who join hands for buying and other purposes have been increasing in number and importance, especially in the grocery field

Each type of retailing has had its golden age—the mail-order house, the general store, and the department store. Whether the chain store and the supermarket can hold their own is debatable. It is also problematical whether the general store or the department store can stage a comeback. The future importance of consumer coöperatives and superettes is not clear. Some observers believe that specialty shops have an excellent chance for growth. It is the opinion of some marketing experts that an entirely new type of retailing, as yet unforeseen, will supplant existing types of stores.

The Economic Significance of Retailing as a Great American Industry

The economic significance of retailing as a great American industry may be surveyed from three points of view: (1) the relative importance of retailing as one of the steps of the marketing process; (2) the costs involved in the retailing of goods; and (3) the importance of retailing as indicated by the Census data.

The function of retailing—its place in the marketing process. Retailing is the starting point of the marketing process. Marketing starts with an analysis of consumer demand, and it is consumer demand that retailers are in such a good position to analyze. A retailer, in part, is the purchasing agent of his customers, entrusted with the duty of buying the right merchandise at the right price and at the right time. Some stores guard the interests of their customers so conscientiously that they maintain testing laboratories in order to be sure that customers are getting dependable merchandise. The store is the representative of the buyer rather than of the seller; it should buy what the customers want instead of selling what the manufacturers want it to sell. Since retailers are the guardians of the customer's interests and since retailing is the focal point of the marketing process, it is truly an indispensable American industry.

Costs of retailing. Retailing is important from the point of view of

TABLE I

DISTRIBUTION OF NATIONAL INCOME IN RETAIL STORES

Year	*National Income (in millions of dollars)*	*Retail Sales (in millions of dollars)*	*Percentage of Income Spent in Retail Stores*
1935........ ..	$55,000	$32,600	59.3%
1936..	65,000	37,940	58.4
1937	67,500	39,930	59.2
1938...	64,000	35,300	55.1
1939...	69,700	37,950	54.5

its costs. Retailers, on the average, appropriate about one third of the selling price of merchandise. This one third, with the exception of a small percentage of profit, is expended by the retailer in the form of salaries, rent, advertising, and other operating expenses. A third of the selling price is a very sizable part, sometimes more than the original producer of the goods received. Retailing is frequently criticized on the ground that it is too expensive a means of distribution. Retailers can assist in the reduction of this expense, which is considered by some to be burdensome upon the public. Even a slight reduction of retailing expense would mean a tremendous saving to consumers.

Retail sales. Retailing is also important in view of the proportion of national income spent in stores. The table given above, based on Department of Commerce data, shows how large a part of the national income is spent by its receivers in stores.

Retail sales by kind of business for 1939 were as follows, according to the census of distribution:

Kind of Business	*Percentage of Total Sales*
Food stores	24.2%
Eating and drinking places	8.4
General merchandise	13 5
Wearing apparel	7.8
Automotive	13.2
Other retail stores	32.9
	100.0%

Large-Scale Retailing[3]

The following table shows the sales volume and percentage of profit obtained in 1939 by some of the leading firms of various types.

TABLE II

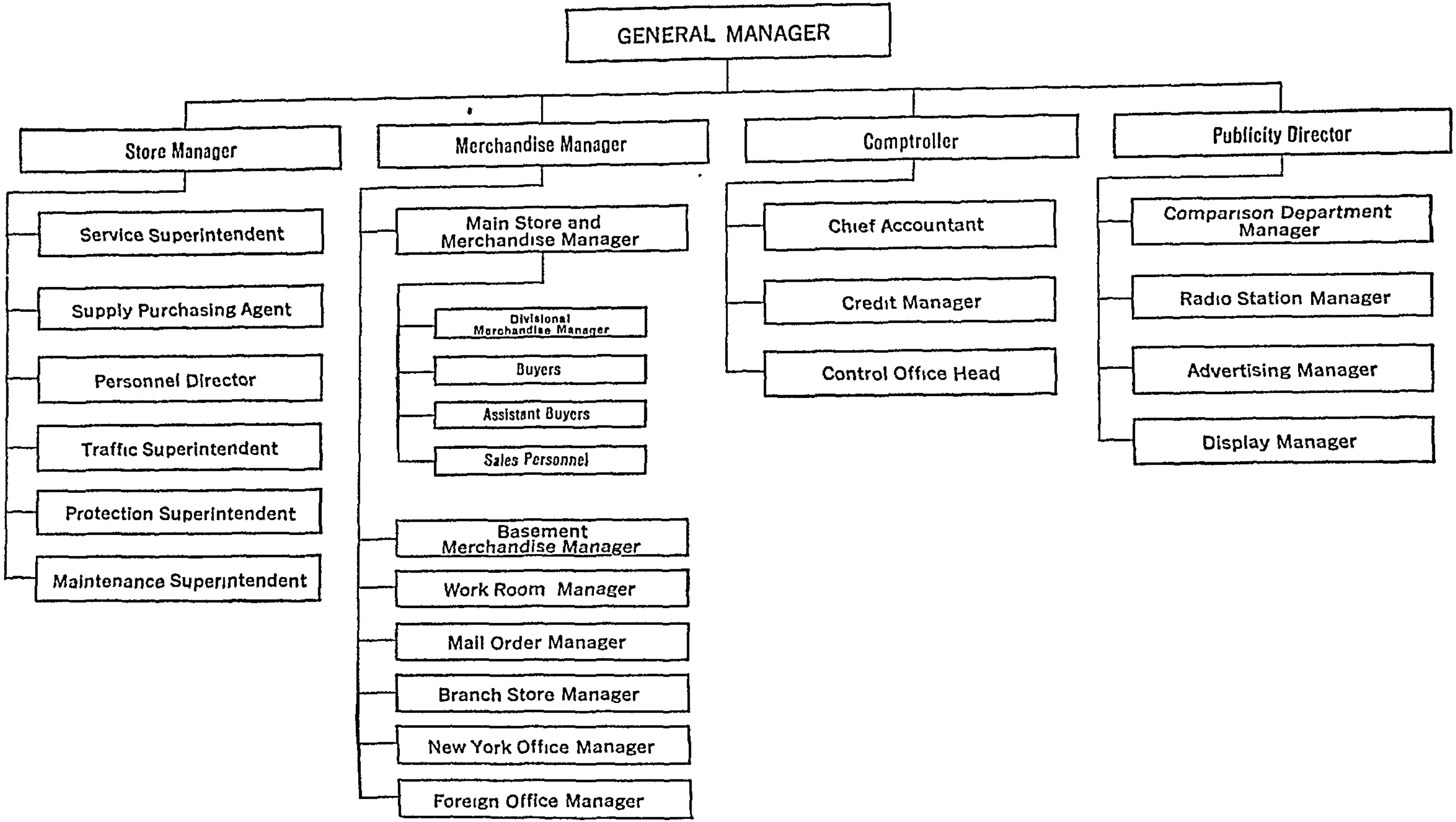
SALES VOLUME AND NET PROFIT OF LEADING RETAIL STORES IN 1939

Type of Store	*Sales Volume, 1939 (in thousands of dollars)*	*Net Profit (percentage of net sales)*
Grocery Chains:		
Great Atlantic and Pacific Tea Co	$990,358	1.2%
Safeway Stores, Inc.	385,428	1.6
Kroger Grocery & Baking Co.	243,357	2.3
American Stores Company	114,824	1.0
Variety Chains:		
F. W. Woolworth Co.	318,840	9.2
S. S. Kresge Co.	152,738	6 8
W. T. Grant Co	103,362	2.7
Mail-Order Chains:		
Sears, Roebuck & Co.	617,414	6 0
Montgomery Ward & Co.	501,819	5 4
Department and Specialty Stores:		
R. H. Macy & Company	84,974	[a]
Allied Department Stores	112,122	4 3
Associated Dry Goods Corp.	60,329	3.3
Gimbel Brothers, Inc.	92,231	1.5
Goldblatt Brothers	47,975	1.7
Bullock's	25,415	5.2
Bloomingdale Brothers	25,465	2 7
Kaufman Department Stores Corp.	25,104	5.0

[a] The consolidated net profit—including R H Macy & Co., L. Bamberger & Co., Davidson-Paxon Co., and LaSalle & Koch Co.—was $2,350,227.

Store grouping. It is significant that nearly every large store is affiliated with at least one other store. For example, R H. Macy and Company is affiliated with L. Bamberger and Company of Newark,

[3] The following discussion is given from the point of view of the large department store in order to cover adequately all phases of retailing



Adapted from Mazur, Paul, "Principles of Organization Applied to Modern Retailing," Harper & Brothers, New York, 1927

Fig. 1. Organization Chart for a Department Store

LaSalle and Koch of Toledo, and Davidson Paxon Company of Atlanta; J. L. Hudson and Company of Detroit is affiliated with the Associated Merchandising Corporation; Frederick Loeser and Company of Brooklyn is affiliated with the Cavendish Trading Corporation.

There are four types of store grouping: (1) associated independent groups, such as the Associated Merchandising Corporation (R.R.A.), which are made up of a group of independent stores, including Abraham and Straus in Brooklyn, L. S. Ayres in Indianapolis, Dayton's in Minneapolis, Filene's in Boston, Horne's in Pittsburgh, Hudson's in Detroit, Stix Baer and Fuller in St. Louis, and Strawbridge Clothier in Philadelphia; (2) ownership groups, such as the Allied Stores, which own or control about 20 stores, including Donaldson's of Minneapolis, The Golden Rule of St. Paul, and Jordan Marsh of Boston; (3) branch-store systems, such as Schuster's of Milwaukee and Wieboldt's of Chicago; and (4) chain groups, such as J. C Penney Company.

Proper organization essential. Since there is necessarily much delegation of authority and responsibility in large-scale retailing, proper organization is fundamental. Lack of organization leads to unwieldiness and inefficiency. A typical large department store has four main divisions: (1) merchandise; (2) operation; (3) publicity; and (4) accounting and control. Each division is in charge of a major executive reporting to the general manager, namely, the merchandise manager, whose function it is to supervise the selection, assortment, and control of merchandise; the store manager, who is responsible for service; the publicity director, whose job it is to bring people into the store; and the controller, whose responsibility lies in expense control. If the publicity division succeeds in bringing people to the store, if the operation division gives the customers satisfactory service, if the merchandise division has the right goods at the right time and at the right price, and if the control division succeeds in controlling expenses, the result is net profit, permanence, and continued good will for the store.

In order to reduce the number of top executives, some stores have cut the number of major divisions from the traditional four to a lesser number, usually three. There is considerable variance of opinion as to which of the divisions can be consolidated to the best advantage.

The factor of markup. Large department stores (having over $10,000,000 in sales volume) have an average markup of about 38 per cent. This means that, if an article costs 62 cents, on the average, it will be marked to retail at $1.00. The markup must be high enough to provide for any markdowns that may be necessary subsequent to the original pricing in order to move the goods and high enough to cover inventory losses through shortages, operating expense, and some profit.

Operating statistics. Operating statistics for large department stores having sales of over $20,000,000 were as follows for 1938 (all figures are based on net sales unless otherwise noted):

Initial markup (percentage of retail)	38.4%
Markdowns	5.1
Gross margin	36.9
Total expense	37.8
Net operating loss	.9
Net other income	3.7
Net gain	2.8
Rate of stock turnover	4.6
Customer returns (percentage of gross sales)	12.7

Payroll expense constitutes about one half of the total expense of a department store. This large amount can be better understood when it is kept in mind that considerably over one half of the employees in a large store are nonselling employees not actually selling merchandise on the floor.

Upward trend of operating expenses. The trend of expenses has been upward for several years, in spite of much effort expended by retailers to reduce them. Chief among the reasons for these increased expenses are: (1) additional taxes; (2) increased salaries due partly to union activities; and (3) additional customer services. When sales volume is reduced because of declining prices rather than physical volume, expenses are not reduced in proportion to dollars of sales volume. This is due to the fact that many expenses vary more directly with the physical volume of goods sold than with the dollars of sales volume.

The problem of returns. Returns from customers are increasing at an alarming rate. Nearly 13 per cent of all goods sold by large department stores is returned again to the store. Even if no markdown is necessary to resell the goods, the expense of selling those goods a second time doubles the expense involved in the final selling. In spite of the educational work that has been done to instruct the public of the evils of returning goods, of the printed instructions on merchandise which tell the customer how to treat it so that it will give satisfactory service, of training the salespeople so that they will sell only merchandise that will stay sold, and of the careful checking of merchandise by the receiving department and testing laboratory to make sure that merchandise is fit for the purpose for which it is to be used, returned goods are increasing In a few instances, a workable solution has been found in the combined efforts of all merchants in a community to control returns.

The problem of markdowns. In large department stores, markdowns, or price reductions, average about 5.5 per cent of net sales. Better buying has tended to reduce markdowns by minimizing slow-selling merchandise, but with rapidly changing styles and rapid and wide price fluctuations, a buyer often finds himself stranded with unwanted merchandise on his shelves.

The problem of buying. A good buyer can do much in buying wisely and in minimizing markdowns, returned goods, and expense. Markdowns are really incurred when the goods are bought; a bad buy is frequently called a "purchase of markdowns." In order to purchase most advantageously, a buyer is interested in four phases of the buying proc-

ess: (1) where to buy; (2) what to buy; (3) how to buy; and (4) when to buy.

Where to buy. The best aid in knowing where to buy is a resource file. This is a card catalogue in which every vendor with whom a buyer has dealt or may deal in the future has a card. The buyer records on the card his merchandising experience with the vendor. Such information as the name and address of the vendor, the terms that he allows, the kind of merchandise that he carries, the prices in which he specializes, the promptness of deliveries, the amount of markdowns that had to be taken in order to move his merchandise, the fairness of any adjustments that were necessary, and the financial condition of the vendor are all helpful in determining where to buy merchandise. Although a resource file is of great importance, it gets out of date rapidly; a good resource last season does not mean a good resource this season. A buyer may get additional information as to where to buy from his market representative, trade journals, classified lists of resources, other buyers, and salesmen. The buyer must constantly visit all reputable houses, whether or not he buys from them, in order to be sure that he is covering the market adequately.

What to buy. Although what to buy requires a knowledge of the merchandise itself, there are several aids that will help a buyer in selecting merchandise An analysis of stock and sales will indicate to the buyer what merchandise has been selling well, at what rate it has been selling, and what is left in stock. Although a stock and sales analysis will tell what did sell, it will not tell what might have sold if such merchandise had been in stock. Therefore, a want-slip system should be used simultaneously. A good want-slip system is very worth while, but even a reasonably good one is difficult to maintain Salespeople are apt to be lax in making out want slips. In stores that require salespeople to hand in want slips daily, there is a temptation on the part of the salesperson to put down a fallacious want instead of handing in a blank slip, which, in her mind, indicates that she has not been as attentive as she should be in recording wants. Even if salespeople do record wants, their descriptions are often so vague as to be useless; they may not even be sure themselves exactly what the customer wanted.

Additional information as to what to buy may be obtained directly from customers through conversation; through salespeople; by comparison shopping in other stores to see what they are stocking and how it is selling; by consultations with the store stylists, whose advice may be useful in forecasting the trend of styles; by style counts, which indicate what people are wearing; and by contact with manufacturers, salesmen, and trade publications

How to buy. The buyer may buy in one of four ways. He may make a trip to the market, buying in vendors' establishments; he may buy by mail through the use of a catalogue, although this method is useful in the purchase of staple goods or reorders only; he may buy from salesmen who call on him at his store; or he may buy through a market representative. Market representation in the form of a resident buying

office arises from the need of having someone in the market to keep in constant touch with market offerings. This need for representation is attributable to three fundamental causes: (1) the increasing importance of style, which necessitates representation in the markets for style goods; (2) the necessity of increasing stock turnover by the shortening of the marketing period, by more frequent purchasing, and by having better selections with small well-selected stocks, all made possible by the use of a market representative; and (3) the necessity of volume purchasing to get buying power without the carrying of large stocks on hand for considerable periods of time. The market representative, by pooling the orders of many retailers, is able to effect savings for client stores. Furthermore, resident buyers, because of their position in the market, are able to get prompt deliveries, good discounts, and advantageous adjustments if the goods are unsatisfactory.

Types of resident buyers. There are five types of resident buyers: (1) the associated resident buying office, which is owned and operated collectively by a group of stores of comparable size and class of clientele; (2) the private resident buying office, which is the New York office of one store, buying exclusively for it; (3) the salaried, or fee, resident buying office, which is an independent organization contracting with retailers to represent them in the market; (4) the commission buyer, who represents his client retailers but collects his fee from the manufacturer rather than from the retailer; and (5) the syndicate resident buying office, which is the buying office of a chain organization.

Resident buyers perform a multiplicity of services. They scout the market constantly in order to be informed. They will buy merchandise for their clients upon request, assist buyers from the client stores in the selection and buying of merchandise, pool orders of their clients so as to effect volume purchasing, and engage in group research in order to make comparative operating and merchandising information available. In the selection of a resident buying office to represent a store, it is important to weigh the services it performs against the cost and to select one which caters to that particular type and size of store.

There is less definite information on how to buy than on how to sell. A buyer is seldom conscious of his technique. Good buyers, however, have an excellent knowledge of prices. They follow manufacturing costs and are informed on market conditions. They possess either a native or an acquired ability to bargain. It is a popular public misconception that vendors have a one-price policy. Higgling is still necessary in many lines, notably in the textile and clothing industries. A square-dealing buyer who keeps his contracts, does not force unreasonable returns of merchandise, is fair in the taking of cash discounts, and sees that bills are paid promptly is in a peculiarly good position when a vendor has a good bargain to be passed on to some buyer.

Determining the selling price. After the buyer has purchased his goods, he must arrive at a price for which the goods are to be sold. He will send out the comparison shoppers to find out the price at which competitors are selling the goods. If the merchandise has a customary

price, the buyer usually has little choice in the determination of the selling price. He must also price his merchandise so that it fits in with the price lines that have been established in the department. Since some of the goods take a very low markup, other goods must be marked up high in order to arrive at a reasonable average markup. The amount of markup that a buyer must average depends mainly upon the expense incurred in selling the goods, the markdowns that may have to be taken in order to move the goods, the stock shrinkage that will inevitably occur, and the net profit that he intends to realize.

Foreign buying. If the goods are purchased in a foreign country, the buying process is complicated by the additional technical processes necessary to import the goods. Some merchandise is bought more advantageously abroad than in the domestic market. Distinction, prestige, handicraft, price, and individuality are some of the reasons why foreign goods are purchased by American stores. Some goods, such as ready-to-wear apparel, are imported for the purpose of copying the style. It is important to keep in mind, when goods are purchased in the foreign market, that the merchandise may not be adapted to American use and that the original price may not be more than a quarter of the cost of the merchandise when it is landed in the United States. Packing, transportation, warehousing, insurance, brokerage, import duty, and many other expenses must be added to the original cost of the goods in order to compute the final cost of the goods delivered at the store. Failure to realize the lack of any relationship between the original cost of the goods and the landed cost has accounted for more than one buyer's "resignation."

Many customers refuse to buy merchandise originating in certain countries Difficulty of adjustment and return of goods, time involved between purchase and delivery, unproductiveness of the capital invested in merchandise in transit, and speculation in exchange rates are additional reasons why the uninitiated should hesitate before entering into direct foreign purchasing. Small stores that do not wish to set up their own foreign buying organizations may buy through foreign resident buyers called "commissionaires."

Coöperative buying. Group and central buying are comparatively recent developments in buying. Although these terms are used interchangeably, there is a difference between them. Group buying is accomplished by the buyers meeting to decide upon coöperative purchases. If the number of stores engaged in the buying group is large, it may be wise to select a committee made up of store buyers who are delegated with the authority to act in the name of the group. Such an arrangement is called "committee buying," as contrasted with "group buying." Central buying is done by one buyer who is empowered by the group to do its purchasing.

A group engaged in group buying usually has someone constantly employed in going around the market looking for suitable merchandise. If dresses are to be bought in a group, this person will probably select 100 dresses to be inspected by the buyers in their meeting. The goods

included in this preliminary selection frequently have no identifying labels, so that selection of the group will be made on a purely rational basis. The buyers usually convene monthly to select the goods they are going to buy coöperatively. Each is committed to purchase a certain number of each of the styles decided by the group, the amount of commitment depending upon the size of store. The group votes on four or six of the 100 dresses. The orders are placed, and the merchandise is sent and billed directly from the manufacturer to the store. The chief advantages of group buying are that buyers need spend much less time in the market, that price concessions due to quantity purchasing are considerable, and that selections represent the combined opinion of many buyers. The objections to group buying are chiefly that it tends to destroy a store's individuality; that the combined opinion of the buyers may be no better than, and sometimes not as good as, the opinion of one good buyer; that the emphasis is placed on price; and that the buyer is sometimes forced to accept merchandise which he voted against.

Central buying tends to transform the store buyer into a department manager divested of buying duties. The buying activities are largely in the hands of the central buyer located in the market. The friction and division of responsibility between store buyer and central buyer is a serious deterrent to central buying. Still, central buying is used extensively, especially by the chains, and with great success. In fact, central buying is fast supplanting group buying in many lines of merchandise.

Buyers activity. After the buyer has purchased and marked the goods, he must assist in their promotion and sale. When the goods are sold, records of various kinds come to the attention of the buyer. Sales analyses, as shown by the unit- and dollar-control systems, indicate what is selling. Slow-selling reports spotlight what is not selling. Inventory analyses show what is on hand.

The merchandise budget. The buyer's stock turnover is the relationship between his sales and his average inventory at retail. In order to keep stocks balanced to sales, a 6-month merchandise plan is worked out by the buyer, merchandise manager, publicity director, store manager, and controller. The 6-month plan indicates the forecast of sales by months. Inventories are planned and expenses budgeted. The plan tells the buyer how much he should plan to purchase each month. The difference between his planned purchases for any month and the amount he has purchased to date during the month is his "open-to-buy." If he wishes to purchase goods in excess of this amount, he must receive authorization from a higher executive. Although the 6-month plan is not an iron-clad plan that must be carried out literally, in spite of any necessary adjustments that appear, it is a good guide, aiding the buyer in the operation of his department.

Charge Accounts

The vast majority of stores extend credit to their customers. In 1937, about 23 per cent of all retail sales were on open-book credit, about 12

per cent were on installments, and the remaining 65 per cent were for cash. The attitude of stores toward credit—that it is a necessary evil—has changed. Credit is used as a promotional device to get additional business. Installment sales have increased enormously from 1937 to 1940. Whereas installment buying was formerly limited to the "hard lines" having a relatively high repossession value, now practically all types of merchandise may be bought in this way by customers.

The cost of granting open-book credit is probably about 3 per cent of charge sales, although the loss on bad debts normally amounts to less than half of 1 per cent. Charge customers return a much greater proportion of their purchases than do cash customers.

Delivery

Delivery is the most expensive customer service. Since the delivery expense averages 12 cents per package, stores have placed special emphasis on the necessity of reducing delivery costs. Turning deliveries over to a consolidated delivery company that delivers for numerous stores has been the solution arrived at by many stores.

Major Present Problems

Among the major present retailing problems are: (1) the maintenance of profit; (2) advertising policies; (3) personnel; (4) stock control; (5) buying methods; and (6) the consumer movement.

Maintaining profit. Profit has been unsatisfactory because of high expenses and markdowns. Customer services have been increasing without a corresponding increase in business resulting from them. There are two possible remedies: an increased markup, or a decreased expense.

Obviously, reduced markdowns, or a higher proportion of high-markup sales, would have a beneficial effect on net profit. Some retailers think that the expense percentage cannot be reduced materially, basing their conclusion on the fact that they have not been able to do much in the way of reduction in the last few years. They claim an increased markup is the only salvation.

The opponents of this contention believe that department stores are already at a competitive disadvantage with other types of retail institutions and that to increase the markup would be fatal. Their suggested solution is expense reduction.

Advertising. A second major current retailing problem is that of advertising. The terrific rush for business has colored the advertising of some retailers. Extravagant claims as to merchandise and prices are seen in newspapers. Many customers, upon looking over the advertisements of stores, come to the inevitable conclusion that someone is lying One of the tasks of retailers is to reëstablish public confidence in advertising.

Personnel. A third problem is that of personnel Frequently, one division of the store can see only its own point of view, refusing to take

a store-wide attitude. Buyers tend to keep information from their assistants for fear that the assistant will know as much about the business as the buyer himself. From the standpoint of customers, the chief personnel problem is that of salespeople. It is a widely spread, and perhaps truthful, conception among customers that department-store salesmanship is bad. Unionization is a new problem confronting stores.

Stock control. Although stock control received a momentary setback by the necessity of making emergency expense reductions, it is still only a partly solved problem. To devise a simple and inexpensive method whereby buyers can get the needed information when they want it, and in such a form that they can and will use it, is a task for the best of retailing brains.

Buying methods. As for buying methods, especially in group and central buying, there is little statistical information that serves to indicate the success experienced by stores using these methods Some stores feel that central buying is a failure. Others believe that group buying is merely a forerunner of central buying and that centralized purchasing, such as is done by the chains, is inevitable for profitable department-store operation in the future.

The consumer movement. The consumer movement is an important one. Consumers are protesting that injurious or misrepresented merchandise is being sold them; they want the facts about the merchandise they buy. Retailers are in a quandary regarding as to what they should do. Some are making a serious attempt to give customers what they want. Affixing informative labels on merchandise telling customers what the goods is made of, what it will do, and how to take care of it is one way in which retailers are coöperating with the aims of the consumer movement. Another way is to encourage consumer education in schools On the other hand, other merchants feel that the consumer movement is the work of busybodies who attack stores and others in order to use up their surplus energy.

Regardless of the present attitude of retailers, the consumer movement is too strong to be overlooked. Those retailers who fail to recognize the suggestions and wishes of customers are shortsighted. Perhaps the time has come when the slogan "retailers are the purchasing agents of the customers" will be taken seriously by retailers.

There are many other present problems confronting retailers. Among these are taxes, credit costs, customer purchasing power, legislation, and other forms of Governmental interference.

The Future of Retailing

When business is not sure of its present status, it is dangerous to forecast forthcoming developments. Although it is quite certain that none of the existing methods of retail distribution will fade out entirely within the next few years, there is a possibility that some new kinds of retailing will come into existence. The exact nature of this new type of retail outlet is, of course, unknown.

One safe forecast is that the general public will take more interest in retailing. As customers, they will have more influence in determining what merchandise stores will sell. Consumer education will be more general, particularly in secondary schools. Better people will be attracted to the retailing business as a vocation. The ethical level of retailing will continue to rise, and its transformation into a profession will be completed.

38

The Hotel Industry

The Early Inn, or Tavern

For those hardy wayfarers who first turned their backs to the Atlantic, travel in America was far from comfortable or safe. There were no roads, no comfortable inns or hotels. A rude stockade in the wilderness was to them a welcome haven. Later, with the growth of towns, taverns were opened. These not only served for the convenience of travelers but were also the center for much of the life of the town. The public house was second in importance only to the meeting house, which was close by. In winter, after a long meeting in the chill of the unheated meeting house, the tavern, with its great fire in the taproom and its bar and convenient chairs, was a haven of warmth and cheer. Here people could hear and discuss the news of the day and transact their various business affairs. The importance of the role played by the tavern, or public house, is evidenced by the fact that, in 1656, the General Court of Massachusetts made towns liable to a fine if they did not maintain a public house, or "ordinary," as they were commonly called.

The courts in many places made strict rulings as to the conduct of an ordinary. In some instances, they ruled that there could be no games played; nor could there be dancing or singing. The price of food and drink was fixed by the court, which, in the early colonial days, generally considered sixpence a fair price to charge for a meal.

With the building of roads and ferries, the number of public houses increased. The name "ordinary" was gradually dropped, and "tavern" was adopted. Gradually, taverns became more pretentious, and after the Revolution, the word "hotel" was found in general use.

The Hotel of Today

The modern American hotel bears only a very slight resemblance to the town tavern or "post-road" inn from which it has developed. The hotel of today is a distinctly modern institution. It did not come into being until the railroads pushed toward the West. The commercial activity following the Civil War brought the first marked demand for

lodging and eating houses on a scale unapproached by the early inn, or tavern.

In New York, it is true, the City Hotel was opened in 1794, "an immense establishment" of 73 rooms. Boston, Philadelphia, and Baltimore also soon boasted structures too pretentious to be classed with the old-time inn; but the "hotel movement" remained at a standstill outside of these Eastern cities until the steam railroad carried commercial travelers westward.

Each year has seen the establishment of new standards of service, safety, and luxury. In each decade, it was felt that the height of efficiency had been reached and that no great forward strides remained. And yet each decade has seen hotels add further comforts and conveniences for their guests.

Today, these huge masses of brick and steel tower 20, 30, 40 stories, or more, above crowded metropolitan streets. Upon the 1,000-room structure that almost staggered the imagination a generation ago now falls the shadow of a "skyscraper" housing 3,000 or 4,000 transient guests.

Economic Significance of the Hotel Industry

Hotels have become, in value and importance, the seventh American industry. In this rating, equal weight is given to the extent of investment, to the number of employees, and to annual revenues.

According to the *Hotel Red Book and Directory*, published by the American Hotel Association, there are approximately 16,000 hotels of over 25 rooms in the United States, containing 1,200,000 guest rooms. The 1935 Census of Business, prepared by the United States Bureau of the Census, showed the existence of 28,822 American hotels. The Census included all establishments reporting more than 6 guest rooms. These establishments provided 1,430,000 guest rooms and represented an investment of $5,000,000,000, with annual revenues of $1,428,646,000. Hotels provide employment for 325,000 employees, who, in 1939, received $300,000,000 in salaries and wages.

It has often been stated—and seldom denied—that no other industry has contributed proportionately to the employment of so many millions in other fields. There is scarcely a manufacturing, commercial, or professional activity unaffected by the construction and daily operation of hotels. No other enterprise so directly or immediately reflects its current position in the commercial life of the community.

In 1940, hotels spent $300,000,000 to serve approximately 1,000,000,000 meals to guests and another 220,000,000 meals to employees. The greatest maintenance item on the hotel budget is furniture, for which the annual bill is $24,000,000. New decorations cost $19,000,000, and kitchen equipment another $9,000,000. The annual bill for plumbing is $8,900,000, and for silverware $1,400,000. Rugs and carpets are renewed at an expense of $7,850,000. In the largest hotels, as many as 4,000 items are found on the storeroom list.

The Hotel Executive

It is more true of hotels than of other commercial enterprises that each unit in the industry is the reflection of a personality. Because the hotel industry has an atmosphere and an individuality of its own, many of the problems involved in its management are unique. Operating plans, organization, and managerial methods that account for success in one hotel may be entirely absent in another which is equally profitable

Physical characteristics of hotels have changed greatly, but no more so than have the intangible human elements that contribute so largely to successful hotel operation. The hotel of early commercial years, like the tavern of Colonial days, was usually managed by its owner and builder. Hotel operation was considered less a business than a genial art. The successful owner-manager was companion, friend, and host to the traveler sheltered beneath his roof. A convivial entertainer, he was "a good mixer" in more than one sense of the word. Today, the alert, progressive, systematic executive is stepping into his place. The hotel industry is alert to the fact that ways must be found to create a margin between the high cost of personal service and rates which still adhere closely to schedules that ruled 10 years ago. The advent of the trained executive is one of the ways in which the industry is trying to solve the problem.

Social Importance of Hotels

In one respect, at least, the modern hotel still carries on the tradition of its predecessors: its manager is the unofficial civic host. His is the one meeting place open to every element in the community and yet dominated by none. It is the one meeting place which lends added prestige to any gathering, be it social, political, or business.

It is almost axiomatic that a community is judged by the character of its leading hotel Manufacturing, commercial, and professional activities find in the excellence of hotel service a very effective medium for community advertising. This to some extent explains the unfortunate overexpansion of hotel facilities in so many cities in the prosperous period immediately prior to the depression of the 1930's. Unless communities assume the obligation of subsidizing the unsuccessful hotel, construction programs should be based only upon the conservative interpretation of a comprehensive, unbiased analysis of needs and probable demands.

Chain Management

In no other industry does the human equation assume greater importance. The hotel reflects a guiding personality. On the purely fiscal side, its gross income bears a lesser percentage relationship to investment than in most industries. Since a hotel operates with such slight margins between gross revenue and expense, its management is given an impor-

tance unparalleled in any other industry. This is one reason for the growth of hotel "chains."

The justification for chain operation goes further, for it gives to the individual hotel the benefit of mass purchasing, of architectural and construction facilities, and of economies in financing. In addition, it provides a compensatory balance to smooth out seasonal and sectional fluctuation in demand.

Some of the larger corporations in the hotel field not only operate but own, build, and plan their houses. Others confine their operations entirely to the management of leased establishments. Still others operate for a percentage of gross or of net income. In some cases, management is considered a professional service rendered for a stated fee, and all income and any resulting profits accrue entirely to the owners.

Regardless of the general system or character of operation, management is always of paramount importance in the hotel field. In no other industry is each step from raw material to consumption so greatly affected by human elements. Every hotel and every hotel organization is the reflection of a personality.

The modern hotel has evolved from no train of discoveries, was brought into being by no inventive genius. Its progressive development has been from many directions and along many lines. It may owe much to the industry or imagination of some one man and yet no less to the organizing ability of another. One may have brought the vision of popular response to personal service and yet have contributed less than another who saw the mass-patronage potentialities of uniform and moderate rates.

Oddly enough, the human equation has gained rather than lost in importance through the growth of chain management. Although the great majority of the hotels in the country are still independently operated, a list of the 10 or 20 dominant personalities in the industry would be made up largely of the heads of operating chains or successful managers of units in the large chains. This would seem to dispose effectively of the argument that chain operation destroys individuality and tends to shape hotels to a common mold. In practice, the chain merely widens the scope for individual influence.

The development of the chain and the erection of hotels having 1,000 or more rooms bring problems unknown to yesteryear's jovial host. The successful operator of a modern hotel must have his predecessor's virtues and, in addition, be an able financier and a capable executive.

The creation of strong chains has enabled hotels to advertise their services nationally and on a scale which no single house could afford. This ability to influence public preference also serves indirectly to maintain and strengthen a general good will, which, in many cases, has protected hotels against unwise or unjust political pressure.

The American Hotel Association

An even greater factor in maintaining legislative contacts, in order to assist in the passage of sound legislation and discourage unstudied or prejudicial laws, has been the creation of local and regional hotel organizations, federated into a strong national association.

The American Hotel Association of today represents practically all of the better hotels throughout the United States, Canada, and Mexico. Every hotel belonging to its local, state, or regional association is automatically affiliated with the association.

Although there are slight variations in the membership standards of local associations, practically every hotel which conforms to legal requirements as to sanitation, safety, and protection of its guests and their goods, and which is not guilty of unfair or unethical trade practices, is eligible to membership in its local body and consequently in the American Hotel Association.

Hotels, Defined and Classified

It is easier to distinguish between the three major classifications of hotels than it is to give an explicit definition of the word "hotel." It is one of those few words which all know but few can define. It is hard to say just where the dividing line is between hotel and lodging house, on the one hand, or between hotel and apartment house, on the other. For the purposes of this chapter, it might be well to accept Webster's dictum that a hotel is "an inn; especially of the better class."

In the hotel industry, three major classifications of hotels are recognized. First, there is the commercial, or transient, hotel, which caters principally to travelers and tourists. The second classification covers hotels more residential in character and designed to provide permanent homes for their guests. The third classification includes the resort hotel, where vacationists and tourists seek rest and recreation over a relatively long period—a week, month, or season.

The commercial, or transient, hotel. The transient hotel once depended almost entirely upon commercial travelers. Today, it is about equally dependent upon motorists.

Transient hotel is, in a sense, a misnomer. There are today very few hotels that do not make a strong bid for permanent guests. Even those that still depend largely upon the casual traveler are appreciating the need—almost the necessity—of increasing the dependable and predictable returns from rentals not influenced by season, weather, or temporary business conditions. Many hotels that are still regarded as essentially transient or commercial actually derive a great part of their revenue from permanent occupants.

Considering the nature of its appeal, the success of a commercial hotel will be determined largely by its location. Although, in the smaller cities, it is usually convenient to all lines of transportation, in metropolitan centers, a site on the outskirts of the city may be more desirable if

quick and convenient access to active business centers is provided. In this case, the type and character of surrounding buildings deserve careful consideration.

In seeking a desirable location, it is usually found that the one best fitted for a transient hotel commands a relatively high price. Due consideration must be given the value of store or shop space which should be rentable at rates which would compensate for the relatively high investment in land. Unless land represents no more than 20 to 22 per cent of the total investment warranted by conservatively estimated returns, a proportionate share of fixed charges should be met by commercial rentals from attractive and well-located stores and shops.

The centrally located transient hotel is meeting new and keen competition from sources undreamed of until very recent years. Now that large business concerns are decentralizing their merchandising activities, commercial travelers are becoming fewer, and the hotel is more and more dependent upon the patronage of motorists. This growing body of travelers has brought about the development of new types of accommodation—the tourist camp, or court; roadside bungalows; private homes along the highways or on the outskirts of cities that offer one or two "spare rooms" to "paying guests." In some sections of the country, this competition is already making unforeseen inroads upon conservatively estimated hotel revenues.

It would be foolhardy to predict the outcome of this unexpected division of patronage. Realizing that these roadside accommodations must eventually conform to the costly hotel standards of cleanliness, sanitation, and social legislation, many hotel operators predict a marked diminution in their number. Others, however, see in them a possible trend of hotel development.

Competition within the established hotel ranks had become extremely keen even before the highway accommodations began to bid for favor. When a modern hotel appeared in any community, the older establishments found they could retain patronage only by remodeling or rebuilding. In the process, the number of available rooms was frequently multiplied in order to distribute the additional investment, and many communities were dismayed to find available business insufficient to fill a profitable proportion of the increased total of rooms. There has, consequently, been fierce competition to develop and offer services, conveniences, comforts, and facilities which would influence the traveler in his selection of a hotel.

Inasmuch as the hotel is the visible and apparent reflection of community activity, there is always a temptation to erect a larger and more elaborate structure than sound commercial judgment would dictate. A hotel is the community's show window. In its promotion, there is a temptation to exaggerate the potential community advertising values of a new hotel. Consequently, the wiser heads in the industry today are discouraging promotional ventures which are not based upon comprehensive and disinterested analytical surveys of local needs.

The need for intelligent estimates of future demand applies to all

types of hotels—to the residential and resort, as well as to the transient. It is in the latter classification, however, that overexpansion has been most pronounced and in which its effect is more immediately felt by an entire community.

The residential hotel. The recent development of residential hotels marks a new and distinct trend in American living habits. It owes as much of its inception to the apartment house as it does to the commercial hotel. It relieves the family from almost the final vestige of household responsibility and care. It is hard to think of a service or convenience not readily obtainable in the residential hotel. Apartments may be rented or leased for periods ranging from a week to one or several years. They may be procured either furnished or unfurnished. If fully equipped by the hotel, the furniture and decorations may often be selected by the tenant. Though dining-room or restaurant service is maintained, each apartment is usually equipped, if not with a kitchenette, at least for private apartment service from a central kitchen. In most of the larger residential hotels, full hotel service is available at any hour. All are equipped with switchboard telephone service. Maid service is provided for all apartments; valet service is either maintained or quickly available through the management.

As with the commercial hotel, the location of a residential hotel is of first importance. The location also frequently determines the specialized field in which the hotel operates. There are several highly specialized types of residential hotel. For instance, there is a growing demand for bachelor accommodations—some exclusively for men, others exclusively for women. These can be likened to club hotels. They cater to busy men and women who spend little time in their rooms. Bedrooms, consequently, are small. Such hotels must furnish extensive recreational and entertainment facilities. A relatively large proportion of space must be devoted to public rooms, including, in many cases, swimming pools, bowling alleys, game rooms, libraries, and the like.

It is essential that the bachelor hotel, making its appeal to businessmen or women, be located in or near centers of commercial activity. It is likewise important that it be convenient to transportation facilities, including such traffic arteries as lead to near-by suburbs and open fields.

The family hotel, on the other hand, must be located with a view to the social status of its prospective tenants. Although communal living offers many economic advantages, the family hotel makes its strongest appeal to those who seek freedom from the bother and annoyance of housekeeping, rather than to those whose first thought must be economy.

Assuming, then, a fairly heavy investment and consequently high return per room, the hotel must be located in the better residential section of the community, with careful thought given to possible future social trends. Transportation facilities must be convenient, adequate, and comfortable, and must permit easy access to high-class business districts. The locality must be quiet and provide adequate shopping and marketing facilities. It must, of course, be free from the smoke and fumes of near-by factories. Of prime importance, also, is protection against the

encroachment of neighboring buildings, which would restrict light. An apartment, to appeal to those who can afford the most comfortable living quarters, must be quiet, light, and airy. For this reason, sites facing parks and wide boulevards and those adjoining churches and permanent low buildings are preferred. Otherwise, adjacent ground should be purchased to protect the investment.

Inasmuch as the establishment not only houses but also feeds, entertains, and otherwise serves its patrons, the successful managers have, in most cases, brought to this specialized field experience gained in the transient hotel. Operating policies, although broadened to meet apartment-house conditions, are essentially those which have proved successful in commercial hotels.

Competition is, of course, very keen, even in communities where only one or two residential hotels have been constructed. Both the conventional apartment house and the commercial hotel are competing with it for the favor of prospective tenants. The apartment house often has the advantage of lower rates, made possible by elimination of services offered by the residential hotel. The commercial hotel, on the other hand, appeals to many whose plans are indefinite; who, for one reason or another, hesitate to sign a lease; or who, even though they may remain for years, do not wish to consider their residence in a hotel as anything more than temporary.

Although the financial problems of current operation differ greatly from those in the commercial hotel, the sound principles of initial financing apply to both. The residential, or apartment, hotel will operate under a severe handicap if more than a nominal part of its revenue must apply to the cost of promoting or financing. No short-term bonds, liens, or loans secured by the property should call for interest payments in the first 2 or 3 years of operation.

It should be expected that the residential hotel, like a commercial hotel, will not be instantly popularized but will probably operate at a loss for the first 2, or perhaps 3, years. Original investors in many residential, as in many commercial, hotels have suffered heavily because of the temptation to finance as largely as possible through mortgage bonds. Since these offer a higher degree of security than capital stock, they are more easily marketed. It should be remembered, however, that failure to earn and pay interest will result in foreclosure and perhaps in a reorganization that will prove costly to unsecured stockholders.

The resort hotel. The need for caution in initial financing applies just as much to the resort hotel as it does to either the transient or residential structure. This is likewise true of location, although here the determining factors bear little resemblance to those which must be considered in hotels of other types. The resort hotel need not be located in a town or city. Its location is determined, rather, by scenic, historical, therapeutic, or recreational values.

Few, indeed, are the resort hotels that can operate profitably through 12 months of the year. In most of them, the season runs for not more than 3 months, with the peak of demand extending over not more than

a few weeks Since complete shutdown and suspension of revenue follow the short seasonal activity, it is apparent that financial hazards are greater and that operation is subject to more elements of chance. An untimely rise or fall of temperature may wipe out a season's profit; inclement weather over a period of but 1 or 2 weeks may result in heavy losses for the entire year. It is imperative that every aspect of need and demand be subjected to careful and unprejudiced analysis before a resort project is seriously considered.

Although chain operation does not exist in the resort field to the extent that it does in commercial or residential hotels, many successful managers of seasonal resorts operate two establishments, one in a southern playground and another in the mountains or along the northern seaboards. As the season closes at one resort, they move their organization and staff of employees to the other.

The resort hotel must provide a variety of features unrelated to food and shelter, the two fundamentals of hotel service. Its appeal is to semipermanent guests, whose stay will range from a week to a month or an entire season. In addition, it must be equipped to accommodate a relatively large number of week-end transients. Not only must the resort hotel feed and shelter the casual tourist, but it must so capitalize all existing possibilities for rest, recreation, and pleasure that it will provide a strong incentive for prolonged stay Although usually located outside the areas of high land values, the fixed investment is necessarily great. Except when located in one of the popular and populous recreational centers, the resort hotel is usually surrounded by large lawns, gardens, and wooded walks It must not only house recreational and club facilities but must offer provisions for outdoor sport and exercise.

A resort hotel capably managed and well merchandised may overcome many seasonal handicaps. The short season prevailing in many of the older resort hotels has been materially lengthened upon their replacement by more modern structures, under more progressive management.

There is scarcely a local feature or value around which a resort may not be created and successfully developed. One hotel capitalizes on surf bathing; another owes its success to springs warmed by subterranean fires; others prosper by locating near the warm waters of southern seas or the ice of northern lakes The foliage of the tropics, the rarefied air of mountain heights, golf courses, or streams stocked with game fish—these and almost any other appeal can be capitalized by a progressive hotel management

In many ways, resort-hotel management accentuates the importance of the human equation. The resort manager meets in an intensified form most of the problems of personal service and of business administration common to other types of hotels. He cannot tolerate costs that are not reflected in remunerative service; for, in a short season, he must meet heavy fixed charges and a necessarily high operating overhead. Even though his rates may be high compared to those in a transient hotel, he is forced to hold them within a competitive range. Most of his guests are vacationing; they seek a change from the strife and turmoil of the busi-

ness world or from the cares and worries of housekeeping. Desiring rest and relaxation, they spend much time in their rooms and a great deal of time in the public rooms of the hotel. Thrown in close contact with the house personnel, they are quick to observe deficiencies and are unusually sensitive to discourtesy or inattention.

Strange as it may seem, managers of commercial hotels in New York and Chicago assert that theirs are the most popular resort hotels in the world. Their assertion is based upon the number of vacationists who yearly spend from a week to several months in one of the metropolitan centers and ignore the attractions of the conventional resort

If this is true, the resort contends with exceptional competition. Not only are thousands of other playgrounds or health centers appealing to vacationists, motorists, and tourists, but the city hotel, with its transient rates and wider variety of hotel and independent restaurants to meet various pocketbooks, can appeal on a price basis unapproachable in a seasonal resort.

Hotel Operation

Regardless of the definition or type by which a hotel can be classified, the most important factor in its success is its location. Its location must permit it not only to capitalize existing values but to anticipate future local trends. This is particularly important for a commercial, or transient, hotel. Transient patronage tends, not only to seek accommodations convenient to transportation facilities—whether rail, water, or highway—but also to follow the shifting tides of local business activity. Unforeseen shifts in commercial activities frequently cause the obsolescence of commercial hotels after a useful life of only 10 or 15 years.

Even though the need for additional hotel facilities may exist in a given community, their provision will prove financially disastrous unless its site makes the hotel convenient, and hence attractive, to those whose patronage must support it.

Interesting features of service to guests and of economy in operation are almost as numerous and varied as the physical characteristics of thousands of modern hotels. When it is thought that no additional service remains undiscovered, some new hotel will introduce innovations which must soon be taken up by its competitors. Where once there was a bath to every floor, there is now, in most houses, a bath to every room. Where once a cheerful bellboy commanded unlimited supplies of ice, there is now often chilled water on tap in every bathroom. Where once electric lights were a novelty, today there must be a reading lamp for every bed.

From "Continental breakfasts," introduced through servidors—and consequently with no need for "tipping"—to secretarial service for busy executives, there is scarcely a service or convenience which cannot be found in some of the better transient hotels. In part, many of them are found in all good hotels.

Trends and Influences

Each decided advance in the development of hotels has followed some revolutionary change in transportation methods. The fortified stockade did not disappear until passable roads connected trading centers and a need arose for the tavern, which afforded rest and refreshment to both passengers and horses. The forerunners of modern hotels received their impetus from the development of rail communications. The trend indicated in their inception was not clearly defined, however, until the rapidly improving sleeping car forced the hotel to strengthen its appeal to the traveler.

The development of automobile travel has seriously affected and strongly influenced hotel operation in the past two decades. With railroads undeniably becoming a secondary mode of tourist travel, the automobile is destined to exert an increasing influence upon hotels. The resulting trend, however, is not even yet clearly defined.

Hotels are already responding, although still in a less marked degree, to the more recent development of air transport, evidenced by hotel construction in conjunction with or adjacent to the more active airports.

Just how these trends will veer and along what specific lines they will develop is still a matter for conjecture. That they portend another distinct step in hotel evolution cannot be denied.

This much is clearly apparent: The new hotel which follows precedent will be hard to justify unless it is located in one of those few communities suffering for want of adequate hotel facilities. There is every indication that hotels are rapidly approaching, if they have not already reached, a climactic point at which the successful operator must establish new precedents rather than follow old ones.

But where the new precedents will lead no man can predict.

39

The Travel Industry

Development of Travel Facilities in the United States

Throughout early colonial days, the popular mode of travel was by boat, for the multiplicity of navigable rivers on the Atlantic seaboard offered opportunities that encouraged this method of transportation. It must be remembered that the New World, although populated by the more adventurous of the Europeans, was nevertheless clinging to travel customs almost as tenaciously as the Old World, where water transport still ruled. The colonists, moreover, found it eminently safer to voyage between colonies by water. Forests were dense, enemies numerous, and settlements far apart.

Water travel had its handicaps, however. Not the least of these was piracy, which was common along the Atlantic Coast as late as 1700. This probably had much to do with the early direction of thought to safer means of land travel. Travel on horseback between villages became more common, especially in the North, where towns were closer together than in the South.

Sail packets. The mail carrier was the father of American land travel, just as today, in his speedy aircraft, he has become the pioneer of travel by air. Traveling on horseback, the postman made regular trips between large towns, carrying messages and bundles. Facilities used by the fur traders, especially the French, who paddled canoes along with the Indians whom they befriended, were primitive. Sail packets offered the most convenient travel facilities and, until the end of the eighteenth century, were the preferred mode of transportation. Many of these sloops were of 75 to 100 tons burden. They carried passengers as well as freight. The popularity of the smaller vessels was partly due to the fact that dockage and pilot charges in New York were less for the smaller vessels. These sloops regularly ascended the Connecticut River to a point 64 miles from its mouth. This illustrates the degree of penetration that this familiar and reasonably safe mode of travel made possible at that time.

The stagecoach. Meanwhile, important strides were being made in travel by stagecoach, although the average colonist depended on the saddle horse. The most famous of the coach routes ran between Boston

and New York, and was later extended to Philadelphia. The stagecoach era can be said to have begun in America in the eighteenth century, but it was not until about 1840 that it reached its height of popularity. This doubtless was due to lack of suitable roads. A stagecoach carrying mail ran out of New Haven, Connecticut, as late as 1869.

Barges on the Mississippi. At the time the stagecoach was bringing Eastern states closer together, the farmers of the Midwest were finding it both difficult and expensive to trade in the Eastern markets. As a result, they fashioned huge barges on which to float their products down the Ohio and Mississippi Rivers to New Orleans. Because of the hostility of the Spanish officers, the Midwest pioneers were frequently relieved of their boats and cargoes upon arriving, but by 1795, a treaty with Spain had granted these farmers free use of the Mississippi's mouth.

Advent of the steamship. Five years earlier, John Fitch, one of the earlier experimenters with steam for water transportation, had succeeded in making regular trips with a steamboat on the Delaware between Trenton and Philadelphia. Robert Fulton was even more successful in 1807, when the *Clermont* made its pioneer trip from New York to Albany before a sceptical audience. The side-wheeler covered the 150 mile trip in 32 hours. It is not generally appreciated that the development of the steamboat in America was retarded by the legal battle which followed the exercise of Fulton's patent rights, which prevented unlicensed steam vessels from entering New York waters. The exercise of these rights caused Connecticut to enact a law ruling that no vessel bearing a Fulton license could enter Connecticut waters. It was not until the United States Supreme Court, in March, 1824, reversed the ruling of the Court of Errors of New York, declaring the act of the New York legislature unconstitutional, that experimentation and development of steamboat lines were able to proceed.

After the War of 1812, steamboats were common on the Ohio and Mississippi Rivers. In ferryboat form, they made regular trips across the Delaware between Philadelphia and Camden, and across the Hudson between New York and points on the opposite shore in New Jersey.

Commodore Vanderbilt's *Traveler*, one of the famous craft of America's early travel history, carried mail and established some early speed records. She was temporarily withdrawn in 1849, when the railroads commenced to figure more prominently.

The Cumberland Turnpike. In 1806, the wagon road came into great prominence in the traveler's consciousness, for it was then that work started on the famous highway between Cumberland on the Potomac River and Wheeling on the Ohio. This turnpike averaged 80 feet in width and, by 1812, had cost the nation $200,000.[1] It was over its stone and gravel surface, winding its tortuous way over the mountains, that

[1] The Cumberland Road was to have been built by the Federal Government out of funds derived from the sales of public lands in the states to be traversed; but additional appropriations soon became necessary, and, largely owing to the influence of Henry Clay, the National Government advanced the sum of $6,821,246 for this purpose.

long lines of emigrant "covered wagons" and pack horses made their way to Ohio With the Cumberland Road began the development of the West.

The Erie Canal. Appreciating the vast importance of water travel and transportation, the State of New York decided to open a waterway through the center of the state to connect the waters of Lake Erie with those of the Hudson River. William C. Bouck, who later became governor of the state, was appointed the first canal commissioner, and under his supervision, the great work was undertaken and completed.

At the time the first 260 miles of the Erie Canal were opened, in 1822, packets, steamboats, and stagecoaches were the only general modes of transportation in this country. When, in 1825, the waters of Lake Erie poured into the completed 360 miles of canal, America sensed wholly new possibilities in travel. Along the canal, cities grew up and flourished. Freight costs were greatly reduced. Travel on the Erie Canal seemed to prove the fallacy of considering any travel project impossible and served, therefore, to do away with many of the prejudices against travel held by the people of that time. Indeed, it created so much enthusiasm that there was considerable overbuilding of canals. Both Baltimore and Philadelphia found themselves hindered by mountains in their efforts to connect with the West. A vast canal project in Connecticut was a financial failure of serious proportions. Before several of the Western states could complete their canals, the newest means of transportation—the railroad—was becoming the center of attraction.

The westward movement. As late as 1830, there were but 48 miles of railways in the United States. The discovery of gold and silver in the West created a mass movement of population westward. Those who were journeying into Utah, Nevada, and California could not wait for the completion of railroads. They traveled either by covered wagon and prairie schooner or, if not burdened with a family, by the overland stage. The "pony express" between St. Joseph, Missouri, and San Francisco was remarkable for its speeding couriers who carried mail to the West

With the granting of more than $50,000,000 to the Union Pacific and the Central Pacific Railroads, Congress gave transcontinental travel the greatest impetus it had ever known. America stepped out of its swaddling clothes of pioneer travel at the great ceremony of May 10, 1869, when the final rail of the Union Pacific was set by a golden spike at Ogden, Utah. The first commercial link between the Atlantic and Pacific had been forged.

Development of American railways. American railways enjoyed an opportunity to reach a higher state of development than did the canals. This was due to the fact that, for more than 50 years following their formative period, the railways enjoyed supremacy as the superior mode of land travel. By 1842, for example, one could travel from Boston to Buffalo by train. Ten years later, Chicago was connected with the Eastern cities by rail. In 1857, Chicago was joined by rail with St. Louis. One of the most significant facts in the development of the railroads was the scarcity of routes running north and south. This

situation rendered friendly intercourse between the North and South difficult at a time when it was most to be desired.

Motor Transport Brings Great Era of Travel Expansion

The bicycle vogue. While the vogue of the bicycle, which reached its peak in public interest toward the close of the nineteenth century, served to widen the individual's travel horizon, it did not hinder progress in railway development Since it did stimulate the paving of streets and smoothing out of highways, the nation, for the first time, commenced to sense the possibilities in simultaneous development of different kinds of travel facilities Previously, one method of travel had always supplanted another, as was well illustrated by the abandonment of canals in favor of the quicker rail service.

Developments in road construction. With greatly improved steamboats plying the inland waters, steamships crossing the Atlantic on regular schedules, steam trains linking together all the important cities and towns, and the bicycle hinting at the possibilities of faster personal transportation, America found itself in a logical position to experiment with rejuvenating the four-wheel vehicle which heretofore had depended for power on Dobbin or his alternatives, the mule and the ox. This was further encouraged by important developments in roads, which had been in process since 1790. The Great National Pike or Cumberland Road, begun about 1806 and finished in 1840, had brought the various peoples of the nation into closer sympathy. Early in the nineteenth century, McAdam discovered that the danger in the usual method of road building was that, in time, the smaller stones sank and so made an uneven surface. Road building took on new impetus with his introduction of the principle of laying stones of uniform size from top to bottom.

Advent of the automobile. Americans were slow to recognize the significance of the vehicle that was to revolutionize not only all concepts of travel but also all forms of travel, namely, the automobile. Already 122 years before the American fathers of the motorcar were being laughed at, a Frenchman, Captain Nicholas Joseph Cugnot, had built two steam carriages that ran over the road under their own power. America was not even greatly impressed by the fact that, in the eighteenth century, Oliver Evans produced a self-propelled wagon, which he drove over the streets of Philadelphia. It is not surprising, therefore, that, when George Baldwin Selden of Rochester, New York, was granted a patent on an internal-combustion engine using hydrocarbon fuel on May 8, 1879, the fact attracted scant attention. Selden was not granted his patent on an engine that would propel a vehicle, however, until November 5, 1895. In the meantime, Charles E. Duryea brought out a gas car that actually ran and thereby established himself as the American pioneer of what has become a form of transportation represented by more than 30,000,000 vehicles in America alone.

Henry Ford's first car appeared in 1893; that of Elwood Haynes, in

the following year. Automobile development was amazingly slow. By 1896, there were only four gas cars in America—the Duryea "Buggyaut," the Ford, the Haynes, and the imported Benz. Alexander Winton made the first sale to a purchaser as late as 1898.

Even with this hesitant start, 22,419 cars were produced in 1904. In addition, the industry turned out 411 trucks, which were to open another chapter in transportation. At the end of 1939—35 years later—there were 26,250,000 passenger cars registered in the United States, in addition to 4,460,000 trucks. At that time, there were 51,550 motor buses in this country engaged in common-carrier operations, with an additional 86,700—all but 1,000 of which were school buses—in non-common-carrier operations. Buses owned by steam railroads totaled 1,700.

Inevitably, the rapid acceptance by the American people of automotive transportation will someday be recognized as one of the most fundamental changes a nation has ever undergone. On a population basis, Americans own 39 times as many automobiles as do all the people in the remainder of the world. One out of every five people in the United States owns an automobile. Theoretically, it is possible for our entire population to ride in our passenger cars at one and the same time.

With increased ownership of motor vehicles, the American nation began a gigantic program of highway construction. Originally, with one of the worst road systems in the world, America, in a few short years, built one of the best. Today, we have one third of the world's highway mileage—over 3,000,000 miles—of which approximately 1,000,000 miles are hard-surfaced and usable the year round.

More than 6,000,000 people, or one out of every seven persons gainfully employed, are working directly or indirectly in motor transport. The average motor vehicle travels no less than 8,870 miles a year, and total annual motor-vehicle mileage in the United States has reached the astronomical proportions of 250,000,000,000.

The automobile appealed because it offered the privacy and unsurpassed convenience of personal transportation and also because of its speed. Indianapolis speedway contests showed an almost steady increase in speed for the 500-mile grind from an average of 74.59 miles per hour, established by Ray Harroun in 1911, to a record speed of 117.20 miles per hour, achieved by Floyd Roberts in 1938. On August 23, 1939, John Cobb, of Great Britain, established a world's land-speed record on the Utah Salt Flats with the amazing speed of 368.9 miles per hour.

Aircraft invention and development. Travel by automobile has benefited extensively through the invention and development of the airplane, which, except for the extent of its public use, has closely paralleled that of the motorcar. Near the close of the nineteenth century, Professor Samuel P. Langley, Otto Lilienthal, and Hiram S. Maxim were experimenting with the heavier-than-air type of airship. In 1903, Orville and Wilbur Wright succeeded in obtaining an actual flight in a machine that stayed aloft for 2 minutes Public aviation did not materialize

until 1908, when Wilbur Wright's flight in France revealed a speed of 27.2 miles per hour.

At the end of 1939, there were 26,250,000 passenger cars in operation in America, as against 13,409 privately owned aircraft. On March 26, 1940, the air-transport industry completed its first full year of flying without a single death and without serious injury. During that year, 2,028,817 passengers were carried a total of 87,325,143 miles. Express carried by regularly scheduled services amounted to 9,514,299 pounds, and air-mail volume had reached a total of 47,041,155 pound-miles per day.

Motor and railroad transportation—Competition and coördination. With the success of the automobile, the horse-driven vehicle was superseded, except for special purposes. The automobile, in its many passenger forms, is rapidly displacing the electric surface car, for it has greater mobility and permits travel, not only over the city streets, but also over any of the nation's 3,065,000 miles of highways. There is too much invested in rail transport, however, to risk the abandonment of this mode of travel. While the Interstate Commerce Commission is struggling voluntarily with the problem of coördinating the various types of transportation, there has developed an intense rivalry between rail and highway transport. Some of the railroad efforts to meet highway competition have been in the direction of enacting restrictive laws, which prohibit certain types and sizes of trucks and which make it difficult to cross a state line. These railroad efforts also have been directed toward imposing a heavier tax burden on highway transport through claims of subsidies of motor vehicles by the Government. In a more constructive direction, the railroad's efforts to meet competition have included the abandonment of unneeded trackage and introduction of streamline trains capable of high speeds; the transportation of passenger cars over long distances at very low rates; and, more recently, the introduction of a system whereby the traveler covers the main stretch of his journey by rail and rents a car through the railroad company when he has reached his intended vacation area.

The fastest scheduled run today is made by Union Pacific's *City of Denver.* Between Grand Island and Columbus, Nebraska, a distance of 62.4 miles, this train averages 81.3 miles per hour. During 1939, the railroads carried 451,039,262 passengers, of which 231,126,013 were commuters.

The air lines are offering much faster transportation. It is possible to cross the continent in 17 hours east to west, from New York to Los Angeles, and in 14½ hours west to east.[2] This compares with a transcontinental crossing in 59 hours by rail, excluding, of course, the 10 hours layover at Chicago.

The tourist is commencing to appreciate the advantage of selecting the mode of travel best suited to his immediate needs, switching from one

[2] The official record from New York to Los Angeles is 10 hours, 3 minutes, set by A. P. de Seversky on August 29, 1938; that from Los Angeles to New York, 7 hours, 28 minutes, set by Howard R. Hughes on January 19, 1937.

to the other for convenience, speed, safety, or economy. The speed records made on the Atlantic by the newest, fastest, and safest liners, as well as the speeds obtained by motorboats, have revived interest in the further development of inland waterways. Organized efforts are being made to shake off the indifference to the development of river routes and canals. History is repeating itself on land and on water.

American travel of tomorrow. In the prospect of American travel of tomorrow, nothing is more stimulating than the possibilities of various modes of transportation stepping out of their own spheres, merging for unusual effects. We see a hint of this in the transcontinental bus, the high-speed passenger car on the concrete express highway, the ship-to-shore plane service of the transatlantic steamships, and other developments that permits the American traveler the maximum of speed and efficiency that he demands of his travel facilities. Pioneer Americans felt themselves fortunate in the mere ability to travel, regardless of the mode. Today's traveler has every facility at his disposal; tomorrow, he will discover new and amazing combinations of these facilities.

The Economics of Recreational Travel

Travel as an industry. Recreational travel is now an industry of enormous proportions. It is reflected in all channels of trade and is a recognized factor in national prosperity. The annual recreational travel bill of the nation has swollen to the point where it exceeds the value of other important basic industries of the country.

Its importance is further emphasized by the fact that, while travel is affected by changing economic conditions, the fluctuations are not nearly so great as they are in other lines of business and industry. It is amply established that recreation is one of the last things that the American people will forego. For example, even in the depths of the depression, in the early thirties, there was a drop of only about 15 per cent in the volume of recreational travel.

On the basis of figures secured from a variety of sources, official and private, the annual travel bill for the United States can be estimated at $6,000,000,000.

Value of travel compared with other products. Comparing this travel bill with the wholesale value of products of other major industries, as shown by Census Bureau figures for 1937, we find that it exceeds the value of all motor vehicles produced by $3,029,000,000; of slaughtering and meat packing, by $3,213,000,000; of steelworks and rolling mills, by $2,670,000,000; of petroleum refining, by $3,453,000,000; of electrical machinery produced, by $4,378,000,000; and of printing- and publishing-industry products, by $3,794,000,000

Travel classified. Classification of the travel bill by types of transportation used by the vacationing millions shows that $5,000,000,000 is expended by motorists, $600,000,000 by those using the railroads, and $400,000,000 by those traveling by bus, air, and water. Expenditures by motorists are figured on the basis of 1939. In that year, it was estimated

that approximately 52,500,000 people were in the vacation army visiting every section of the country. This estimate is based on inquiries sent to American Automobile Association motor clubs located in the principal touring areas, together with information from a variety of other sources. The railroads, steamship lines, and air and bus lines have no means whereby they can make a detailed segregation of recreational travel as distinct from total passengers transported. However, on the basis of reports on the use of various types of transportation by the nation's travelers, it can be estimated that, of the $1,000,000,000 spent by travelers using means other than passenger cars, about 60 per cent, or $600,000,000, was spent by those using the rails; about 30 per cent, or $300,000,000, by those traveling by water; 7.5 per cent, or $75,000,000, by vacationists using the air lines; and 2.5 per cent, or $25,000,000, by those traveling by bus.

The tourist dollar. An analysis of the distribution of the huge sum spent for recreational travel shows that the tourist dollar finds its way into all channels of trade.

In the case of motorists, 20 cents of the travel dollar goes for transportation costs, such as gasoline, garaging, and accessories purchased en route; 20 cents for hotels and other types of accommodations; 25 cents to retail stores—largely expended by women for such things as linens, lotions, postcards, beads, baskets, blankets, and a large variety of other things; 21 cents to the restaurants; 6 cents to confectioners and wayside stands; and 8 cents to theaters and other places of amusement. These figures, of course, are approximate, but they are close enough to show that the tourist dollar not only benefits one or two classes but finds its way into a great diversity of channels and has a vital bearing on our whole economic structure.

According to this breakdown, garages and service stations serving motorists get about $1,000,000,000 as the transportation share of the motorist's travel bill; the hotels and inns receive an equal amount of $1,000,000,000; $1,250,000,000 accrues to retail stores and related interests offering their wares to motor tourists; $1,050,000,000 is spent in hotel dining rooms and restaurants; $300,000,000 helps fill the coffers of confectioners and proprietors of wayside stands; and $400.000,000 is spent in theaters and other places of amusement.

That these expenditures are confined to no one section but are distributed over the entire United States is evidenced by a survey of motor-travel preferences made by the National Touring Bureau of the American [illegible]tomobile Association. In response to the question, "What is you[illegible] [illegible]nd in [illegible]on in the United States for motoring?" 34.4 per cent chose [illegible] crossing [illegible]rn states, 19.1 per cent preferred the Western states, 13.7 the [illegible] Chicago. [illegible]tes, 12.9 the Middle Atlantic states, 9.6 per cent the Great [illegible]is and Ohio River Valley states, 6.6 per cent the North Central states, and 3.7 per cent the South Central states.

Selling Travel to the Public

The sale of recreational assets and the promotion of travel has become a highly competitive and well-organized business. It employs all the resources and techniques of twentieth-century salesmanship. There is hardly an area in the vast domain of the United States that does not possess some recreational assets which progressive citizens are constantly trying to sell to those who travel.

Tourist trade encouraged by the states. Manifold interests are engaged in the development of the travel industry. Nearly all the state governments are now making it a part of their official business to sell their scenery, their history, and their climate. They realize that, apart from the large sums of money brought into communities by the traveler and recreationist, the tourist who today visits primarily for pleasure may become a citizen tomorrow. The states have also come to realize that the natural resources of recreation can be fully exploited without in any way exhausting them, as in the case of most natural resources. They have also learned that recreational assets, like any other commodity, must be merchandised. As a result, a "recreation" item is now found in the budgets of virtually every state; it covers the expense of developing and maintaining parks and reservations, historic monuments, and other essentials necessary to uphold the prestige of a state as a travel objective.

How important these state activities have become in promoting the industry of travel will be readily appreciated from the Bureau of Census figures dealing with operating costs of state governments. The budgets of all states for recreation increased from $878,646, in 1915, to $6,815,000, in 1937, the last year for which complete figures are available This tremendous gain of more than 650 per cent reflects official recognition of the commercial and economic value of the tourist and travel business.

United States Government's contribution. The United States Government is vitally interested in the promotion of travel and recreation. It maintains magnificent national forests and parks, and battlefields and monuments rich in historic interest, at a cost of some $76,000,000 a year. In addition to its guardianship of the public domain as a playground for all people, the Government makes a notable contribution to sport and travel through the constructive work of the Bureau of Fisheries, which keeps our streams well stocked, and through the Bureau of Biological Survey, which performs a vital service in connection with the preservation of wild life. That the Government's investment is serving its purpose is demonstrated by the fact that approximately 48,250,000 people enter the national forests, national parks, and other Governmental recreational areas during the course of a year.

For many years a silent partner in travel-promotion activities, the Federal Government has of late taken a more active part. In February, 1937, there was established in the Department of the Interior a United States Travel Bureau, designed to promote travel within and to the United States. The bureau was to have a dual function: first, to

serve as a clearing house for distribution within the United States of literature describing domestic travel objectives; and, second, to advertise abroad the advantages of travel within the United States. In this, the Federal Government was following the lead of many foreign nations that, for a number of years, have been actively competing for the American tourist dollar. The bureau was set up on an emergency basis and was manned largely by personnel drafted from other bureaus of the Department of the Interior and from various Government reëmployment setups, such as the Works Project Administration. An attempt to have a bill passed by Congress providing a special appropriation for this activity was successful in the summer of 1940.

Competition in selling recreational facilities. Competition for the tourist dollar between states and communities is intensely keen, and is becoming more so due to increased recognition of the value of tourist patronage. The Maine Development Commission, the New Hampshire Planning and Development Commission, the Virginia State Conservation Commission, the Kentucky Progress Commission, the North Carolina Department of Conservation and Development, the Idaho State Planning Board, the Greater North Dakota Association, the State of Wyoming Department of Commerce and Industry, Californians, Incorporated, the All-Year Club of Southern California, the Ozark Playgrounds Association of Missouri, the Mississippi Advertising Commission, the New York State Publicity Bureau, the Denver Convention and Tourist Bureau, Montanans, Incorporated, the New Mexico State Tourist Bureau, and the Michigan Tourist and Resort Commission, which coöperates with three other regional tourist bureaus within the State of Michigan—all form but a partial roster of the state and regional organizations that are engaged in an intensive effort to sell the recreational facilities of their respective territories

Advertising, publicity, lectures, pictures, special bureaus, and travel representatives are mobilized in the selling campaign. No medium is overlooked. One has only to scan the national magazines, run through the resort section of any one of a hundred newspapers, scan the many publications of the American Automobile Association, or turn the dial of the family radio to realize the extent of competition for the tourist dollar.

Cost of travel promotion. It is estimated that, in 1930, a total of $50,000,000 was spent to advertise travel objectives and playgrounds in the United States. By 1939, this total had probably risen to between $75,000,000 and $100,000,000. Contributing to this expenditure were states, communities, regional organizations, railroads, steamship companies, hotels and hotel associations, bus companies, oil companies, and many other business interests that have either a direct or an indirect interest in the dollar of the traveler.

In the past 10 years, the travel-advertising field has been marked by an increase in advertising expenditures by states and a decrease by railroads, with some increase by others interested in the travel dollar. Figures of the Census Bureau show that, in 1929, state budgets contained

approximately $760,000 for promotional purposes. At the end of 1939, 39 states had set up state-financed promotional agencies, and annual appropriations had reached the figure of approximately $4,500,000 a year. Community-travel promotion, meanwhile, has made rapid strides both as to quantity and quality, with total travel expenditures by local communities roughly computed—in the absence of definite figures—at about $15,000,000 in 1939, as compared with approximately $5,000,000 in 1930.

In contrast with the increase in official state and local tourist-promotion expenditures is the decrease in the travel advertising of the railroads. In 1929, rail carriers spent a total of $18,714,471 in passenger advertising of all types; by 1938, this figure had dropped to $8,887,976. The decrease in amount of money spent by the railroads in advertising any particular section of the country has probably been even greater than that indicated by these figures. Ten years ago the railroads spent a large part of their advertising dollar in describing the travel advantages of the respective territories they served. Today, a substantial portion of the railroad advertising dollar is still spent for this purpose, but an increasing proportion has been spent in selling the advantages of the railroad as compared with other types of transportation.

Travel-selling mediums. Among the more important instrumentalities of selling travel are folders, maps, and tour publications, of which an enormous volume is produced every year. The American Automobile Association, for example, annually issues some 60 major publications, including state and regional maps, tour books, and directories, and approximately 1,000 separate strip maps, with a total circulation in excess of 10,000,000 copies. It can safely be estimated that fully one fifth of the total bill for travel advertising goes into the printing and distribution of these publications.

Foreign bids for American tourists' business. For many years, competition within the United States was spurred by the strong bid that foreign countries, foreign steamship companies, foreign railroads, and foreign private agencies made for the dollar of the American traveler. In the heyday of foreign travel, in 1937, *at least 50 foreign agencies were* on the job every day in the year, in New York City alone, selling foreign travel and foreign recreation in competition with the home market. However, constant diplomatic crises in Europe and, finally, outbreak of warfare in September, 1939, put a period to these activities.

With overseas travel lanes closed, the travel agencies of the Western Hemisphere redoubled their activities, and, in furtherance of the program, President Roosevelt proclaimed 1940 as "Travel America Year." A collateral effect of these developments was an intensified interest in the all-American highway, which is planned to extend from Alaska to Argentina and join by highway the republics of the Western Hemisphere.

Trends in Recreational Travel

It was inevitable that the new mobility, awheel, awing, afloat, should make a deep imprint on travel of every description. The fast tempo and diversity of modern transportation has brought about revolutionary changes in the demands of the traveler and in the standards of catering to these demands.

Nomadic spirit of travelers of today. With the automobile parked around the corner, with railroad, steamboat, airplane, and bus companies offering preferred schedules along the great travel lanes, the traveler and recreationist of today has a feeling of independence quite unknown to the traveler of other years. He can move on at a moment's notice; let boredom intrude or let dissatisfaction in any form crop up, and your modern traveler is on his way.

The traveler of today is deeply tinged with the nomadic spirit. Any agency catering to travel or recreation that does not recognize this newly found independence is doomed. It has no place in the modern travel picture, and this is true irrespective of the class of population the agency is catering to and irrespective of the type of accommodation.

Demands of the traveler today. The idea of travel for vacation purposes has moved far from that of mere rest and gazing at pretty scenes. Fathers and mothers were content with easy loafing and quiet surroundings, with sunsets, mountains, lakes, or sea, whether in calm or stormy mood. But son and daughter want a great deal more. Their travel and their recreation must provide a strong dash of adventure. Varied entertainment is, therefore, as important a part of the recreational travel program as good food, an appealing location, or an invigorating climate, and the entertainment provided runs through the entire range of modern sports and adventuring.

Take a glance at a few of the millions of folders selling travel and recreation and note what they offer—not alone scenery, historic interest, good food, and good air, but also dancing, golfing, tennis, swimming, yachting, motorboating, aquaplaning, hiking, horseback riding, mountain climbing, hunting, fishing, motoring, and perchance flying, not to mention a large category of winter sports that are fast developing into a great recreational attraction.

It is estimated that the sports bill paid by the American people in a year amounts to at least $1,500,000,000. Of this sum, a not inconsiderable portion is expended by the agencies catering to recreational travel in order to meet the demand for outdoor play activity.

In a general way, of course, the demand of the traveler varies with individual preferences, with the tastes, home standards, and pocketbooks of the vast number of individuals who compose our gigantic travel army. Moreover, the traveler of today is prone to seek a vacation area in which he can pursue his favorite hobby, whether it be photography, archeology, geology, collecting antiques, fishing, model-boat sailing, or any of the thousand and one other hobbies that Americans have adopted so enthusiastically with increased leisure.

The appeal of travel must be wide enough to catch the imagination of the many different types of travelers, and it must attract the new as well as the old generation of travelers. The appeal must run the gamut from the strenuous life to complete relaxation.

The traveler—a buyer of recreation. Sit in on a family conference on the selection of a vacation point. The discussion is very earnest. Many points of view are presented: Shall it be the North Shore of Massachusetts? Shall it be Rangeley Lakes? Shall it be Murray Bay in the Canadian wilds? Shall it be the national parks? Shall it be a dude ranch in New Mexico? Shall it be the Pacific Northwest? Shall it be Nova Scotia, Alaska, Hawaii, or any one of a thousand objectives, each with its particular appeal and all brought within easy reach by the marvelous travel facilities of today? Folders setting forth the offerings and opportunities of these places are eagerly scanned. But the main interest in the conference, as far as the light it throws on the mental attitude of the modern traveler is concerned, are the points that are probably not discussed at all.

As likely as not, the comparative proximity of the various places under consideration is not discussed. The time to be spent at any point is not decided upon; nor is the rate to be paid considered. Why discuss distance when good roads are taken for granted? Thus it is that distance, as such, means much less than it did in times past. By the same token, proximity of vacation points to large centers of population, while still an advantage from the standpoint of the week-ender, is not the big advantage that it formerly was. Why discuss length of stay at any one place, when the stay is indeterminate and depends wholly on satisfaction? Why discuss costs, when vacationists know very definitely what they want and how much they will pay for these things. They have developed the attitude of buyers—buyers of recreation offered in a great variety of forms on all sides. They shop for it as they shop for any other commodity, knowing that, by doing so, they can make advantageous purchases. They know that no dollar is as eagerly sought after as the dollar of the holidaymaker, and they have learned to take advantage of the extremely keen competition that is motivating the traveler and recreational business today. They have come of age.

Meeting customers' demands. The agencies catering to travel well recognize this maturity. Evidences of this recognition are encountered wherever one turns: an enormously widened range of opportunity for play, a higher standard of food, better sleeping accommodations, reduction of rates in a keenly competitive business struggle, electrification of railroad lines and more comfortable seats on trains, the daily introduction of new safety and convenience factors in airplane travel, an enlarged motoring service along the highways for the 52,500,000 people who annually travel for recreation over the gasoline trail, de luxe equipment for buses, and even a better looking home for his American Majesty, the hot dog.

Agencies catering to the tourist have become aware that travel patronage is largely a repeat business. A survey by the American Automobile

Association showed that roughly 65 per cent of their members had chosen a vacation objective because of a previous visit or because of recommendation of friends. Accordingly, communities interested in tourist business are expending ever-increasing efforts in making things easy and comfortable for the visitor. Such activities include the provision of adequate highways, adequate parking spaces, adequate route numbering, efforts to prevent gouging through exorbitant rates, more lenient enforcement of traffic laws in respect to the visitor, and many other efforts to extend a welcoming hand and to surround the visitor with an aura of courtesy.

Social and Educational Effects of Travel

A decade or more ago, psychologists and commentators were prone to express alarm over the fast tempo of the travel age. In the movements of millions of people hither and thither, these prophets of gloom saw little more than a fierce restlessness of spirit driving us nowhere at 100 miles an hour. Today, however, it is generally realized that the urge to travel is as natural and acceptable an American phenomenon as baseball, double-feature movies, and political conventions Rather than evidencing neurotic symptoms, the American love for travel today is diagnosed as a resurgence of the love for new horizons that drew our forefathers to this country.

Travel and the social structure. The mobility that has been provided the American people has had a definite effect on our social structure. It is true that changes in social organization come slowly and lag at a considerable distance behind industrial developments that affect living conditions and living standards. But it is not too early to see that the revolutionary changes in transportation and in communication which ushered in the travel age have had a marked effect on human behavior and on human outlook. Obviously, the more contacts a man has with his neighbors or strangers, the more horizons his mental and physical vision embraces, the more competent he becomes in the difficult art of living.

Bigotry, parochialism, and intolerance are largely the stepchildren of isolation That modern transportation awheel, awing, afloat has extended the frontiers of the average man and woman, has broken down the barriers of isolation, no one will deny. This change means many things; above all, it means mass participation in a larger life.

Travel—a factor in national homogeneity. A storekeeper from Iowa meets a storekeeper from Georgia at a roadside camp in Maine. What is the range of their conversation? Of course, it will cover business and politics—the price of hogs and cotton and the activities of the Governmental farm agencies; of course, there will be pardonable reference to their pride in their respective homes. But as likely as not, they will talk for the most part of the places they have visited and the things they have seen, things of gorgeous scenic appeal or of rich historic interest. Perchance, they will talk of Yellowstone National Park, of

the Grand Canyon of the Colorado, of the California redwoods and missions, of the sights and glories of the national capital—the National Museum, the Pan-American Union, the National Cathedral—of Mount Vernon, of Monticello, of the battlefields of the Civil War, where men from Georgia met in mortal combat with men from Iowa, or of Gettysburg, the site of Pickett's charge. There may be a good deal of immaturity and lack of discrimination in the discussion. But they have made a beginning; they have started to see America—and to see is at least a start in the understanding and appreciation of a common inheritance and a common obligation.

It is no little thing, the mobility that has been put within the grasp of the average American. In spite of everything, a nation as sprawling as ours, composed of 48 sovereign states, has in it the possibilities of sectional discord that has broken out in the past and might again break out except for the intercommunication that has resulted from our modern transportation facilities. In addition to doing away with sectional discord, this new mobility has, to all intents and purposes, ended the traditional discord between the city and the country. The antagonism between country bumpkin and city slicker that once was so well marked has all but disappeared. To no little extent, this interchange of people within our borders has also played a part in preventing our language from breaking up into mutually incomprehensible dialects, as has happened in nations not so well equipped with facilities of travel.

Of course, it takes more than a smell of gasoline, adjoining seats in a Pullman, or meetings on the veranda of a hotel to make the whole world akin. But the important thing is that there is a constant broadening of knowledge and interests, and that social intercourse is encouraged. And these common interests and this intercourse have led to better understanding and a greater degree of national homogeneity.

Travel fosters historical interest. Nowhere has travel, and particularly motor travel, exercised such an important educational influence as in the domain of history. The rate at which historical and biographical books have been emerging from the presses in recent years is not an isolated phenomenon. It is not due entirely to an awakened interest in history on the part of the colleges. More likely than not, it reflects a greatly intensified interest on the part of the American people in their history and in the great characters who helped to make it.

Questionnaires distributed by communities and by organizations have disclosed that no other asset in a touring area, not even scenic grandeur, evokes a greater interest and appeal than historic memories, monuments, and relics. The truth of the matter is that the American people are fast relearning their own history. The legends and folklore of the textbooks are being translated into living drama, as millions of people visit and revisit thousands of shrines in all parts of the country. It is inevitable that personal contact with the actual locale of dramatic historic incidents, with the homes of national leaders of other years, and with the scenes of their activities, whether battlefields or farms, should develop a keener appreciation of former times. Such contacts make for reverence.

One sign of this mass interest in historical things is to be found in the actual rebuilding of old towns such as Williamsburg, in Virginia, which, from the very early days of a straggling civilization along the Atlantic shore, held aloft the torch of learning and political independence; and Schönbrunn, the famous Moravian mission of Revolutionary days, which was rebuilt and dedicated as a memorial park by the State of Ohio.

Today, the City of Washington has become a mecca for tourists, a great number of whom are boys and girls just graduating from high school. This is serving to enhance the interest of the younger generation in the actual working of the Government and may perhaps lead to a more active participation in it.

Mobility and the standard of living. While, of course, car ownership as such cannot symbolize progress, mobility, and particularly the mobility derived from the automobile, it is affecting the standard of living. Just as ease of travel and the multiplicity of travel agencies bring the city nearer to the country, so they bring the formerly isolated small town and even the rural home within easy distance of those things that the city offers. As far as the cities themselves are concerned, the automobile and other travel agencies have rendered the distance from the home to the office of less importance than it was in the past. Just as isolation drove rural youth to the cities for many decades, so mobility is bringing about the development of model communities within easy reach of the skyscraper office. These communities, participating as they do in both rural and urban life, are beginning to close the gap that grew between city and country during the era of America's industrialization.

40

The Banking Industry

Early History of Banking

Our knowledge of the earliest banking methods and practices is rather meager. We do know that, as early as the ninth century B.C., use was made in Assyria of such commercial instruments as promissory notes, bills of exchange, and transfer checks, which served somewhat the same purpose as the modern bank check. But it was not until after the rise of Athens and Rome that such banking operations as were conducted came under official regulation.

One of the handicaps in these and other international trading centers was the lack of uniformity of coins. It was thus natural that agencies, or "banks," should be organized to convert the coins of one country into those of another, the proprietors being called "money changers." Money changing, then, was one of the first forms of banking conducted on a wide scale and, as may be seen, it arose primarily from the needs of international trade.

A second difficulty in financing foreign-trade transactions was the inconvenience and danger attached to carrying money on one's person or of dispatching actual coins by ship or otherwise over long distances. This led to the practice of depositing money with the money changers, at first for transfer to the center in which goods were being purchased and, later, for the purpose of safekeeping. The money changers gave receipts to the traders for the "deposits" thus made and, if desired, issued transfer orders for such sums as were required for the purchase of goods at other trading centers. As these transfer orders were used as instruments for making foreign-trade payments, they were not unlike our modern bill of exchange.

The use of promissory notes is evidence that the extension of credit, on some basis, was an early banking function; but to what extent the Athenian, Roman, and other money changers issued transfer orders or other instruments to merchants on any basis other than the deposit of metallic money is not clearly indicated. Some references can be found to loans of various kinds, but there is no description of borrowing operations based on well-established and widespread practices.

Little or no further development of banking is discovered until the

eleventh century, which marked the revival of trade and the renewed circulation of metallic money. During this period, there arose the practice of transferring the title of funds left on deposit with money changers and goldsmiths. To effect the transfer, it was necessary for the depositor himself to make the proper entries on the books of the goldsmith or money changer. This marked a second step in the development of deposit banking. Successive steps may be briefly indicated as follows:

In 1587, the Bank of Venice accepted foreign coins of all kinds at their value as bullion, giving the depositor a certificate promising to deliver an equal amount of bullion on demand.

The Bank of Amsterdam, organized in 1609, accepted deposits of various kinds of coins and, after determining their value, credited the depositor in terms of standard coins of equal value. After following for a period the personal transfer method previously referred to, the bank permitted its depositors to transfer their credits to others by means of written orders.

In England, following the confiscation by Charles I, in 1640, of the deposits in the king's mint, people began to deposit their money with the goldsmiths, who issued demand promissory notes therefor. These notes, issued to the order of the depositor or to bearer, began to circulate as money. Since there was no great demand for their immediate redemption, the goldsmiths began to make loans and issue additional notes on the basis of the funds which naturally accumulated. Because of these activities—accepting deposits, making loans, and issuing notes—in time, the goldsmiths came to be known as "bankers" and their notes as "bank notes." The danger and inconvenience attached to the personal keeping of bank notes, received in exchange for coin or bullion or representing money borrowed, led to the practice of leaving the notes on deposit and receiving credit therefor on the books of the bank. The extension of credit by the issuance of bank notes and the practice of leaving the proceeds of loans on deposit with the lending bank were distinct steps forward in the development of banking as we know it today.

The goldsmith-banker was not limited in any way as to the amount of notes he might issue, as, for example, by being required to maintain a given proportion between coin on deposit and notes issued. While this absence of restrictions on note issues made possible the expansion and contraction of currency in accordance with the fluctuations of trade, the lack of automatic redemption facilities caused the issuance of notes in excess of the amount needed. This led to a rise in prices which caused merchants to increase their loans and this, in turn, brought about additional note issues and a further rise in prices. Confidence in the financial structure being finally shaken, the demand for the redemption of notes became so heavy that banks were forced to suspend specie payments. Financial panic and the partial paralysis of commerce ensued.

As a result of these disturbances, there arose a school of thought advocating what is known as the "currency principle." This school holds that bank notes should be secured up to 100 per cent of their par value by gold or government bonds. Opponents of this principle advocate what

is termed the "banking principle," which takes the position that bank notes need be secured only by the assets of the bank if adequate redemption facilities are maintained and that coin should be kept only in a sufficient amount to maintain specie payments. The banking principle has predominated in the note-issue provisions of most countries other than the United States and England.

History of Banking in the United States

Colonial banks. Although the first real bank was not organized until the closing years of the Revolutionary War, the urgent need for money during the colonial period caused the various colonial governments to issue paper money and gave rise to a large number of private banks organized for the same purpose. In organizing the private banks the usual course of action was somewhat as follows:

A group of colonists would agree to organize a bank. There would be no capital stock. The subscribers would merely promise to take a certain number of notes and guarantee to keep them in circulation. They would consent also to receive the notes in payment for any goods that they might sell to the bank; thus the bank was not concerned with the receiving of deposits and the cashing of checks. It issued notes and engaged in various kinds of commercial activities. The notes were secured by land mortgages given by the subscribers to the association. In addition, in some cases, the issues were secured by certain imperishable commodities. The notes commonly bore interest. Generally, they were inadequately secured, unregulated as to amount, and soon discredited because proper provisions for redemption on demand were lacking.

It is believed that the first of these "land banks," as they were called, was organized in Boston in 1714. The scheme became very popular. Many such institutions were established, but in time all failed, with great losses to the public and to the subscribers. Banks of deposit such as were in operation in England at the time were unknown.

Bank of Pennsylvania. During the Revolutionary War, patriotic citizens in Philadelphia organized the Bank of Pennsylvania to assist in financing the war. The first notes issued in 1780 were interest-bearing and payable at a future date. Subscriptions to the fund by the shareholders were secured by bills of exchange drawn in pounds sterling against revolutionary envoys in Europe.

Bank of North America. In 1781, Robert Morris, superintendent of finance under the Revolutionary Government, obtained the approval of the Continental Congress for the establishment of the Bank of North America. The primary purpose of this bank was to assist in financing the needs of the army by loans to the Government in anticipation of receipts, and to create the necessary organization for transferring funds from one part of the country to another and for extending the use of credit, both abroad and at home, by discounting the bills of those who had claims against the Government The new bank took over the assets

of the Bank of Pennsylvania and assumed its liability on the foreign bills outstanding. Since the Continental Congress was a revolutionary body, there was a general feeling that the chartering of a bank was beyond its jurisdiction. Accordingly, a charter was obtained from the State of Pennsylvania in 1782, under which the bank continued to do business until it was absorbed into the national banking system of 1863.

The capital of the Bank of North America was $400,000, of which the Federation, that is, the government of the colonies under the Continental Congress, subscribed $250,000, paid for with silver borrowed from France. Under the direction of the bank, this silver was far more effective as the reserve for a substantial note issue than it could have been if used directly to purchase supplies. The bank loaned $1,249,975 to the superintendent of finance for use in carrying on the war. Most of this amount was repaid in cash by the Revolutionary Government, and the balance by surrendering the stock in the bank which it owned.

Massachusetts Bank. In 1784, the General Court of the State of Massachusetts granted a charter to the Massachusetts Bank. The charter provided for a capital of $300,000 and for the issuing of notes to be secured by the general assets of the bank. At first, no limit was placed on the amount of notes that might be issued, and in spite of the fact that the total exceeded the proportion to capital which might now be considered safe, the notes usually circulated at par. Through the operation of Gresham's law, specie was attracted to New England from other sections of the country, because, in New England, paper money was readily redeemable.

In 1792, a law was passed limiting the notes and other liabilities of banks to "twice the amount of their capital stock in gold and silver actually deposited in the banks and held to answer demands against the same." Deposit liabilities could be created only by the deposit of actual money; and payments were made, not through the use of checks, but in money. The charter prohibited dealing in merchandise and bank stocks. The success of the Massachusetts Bank attracted attention, and thus the bank became a model for other banks in New England and in other parts of the country.

Bank of New York. In 1784, Alexander Hamilton assisted in establishing a bank in New York City. It operated under the articles of association drafted by him until 1791, when it received a charter from the state. Under this charter, the liabilities of the bank, except to depositors, were limited to three times the amount of its capital. The function was primarily that of a bank of issue. It was specifically prohibited from dealing in merchandise or bonds, either of the states or of the United States; neither could it make loans on real estate. Deposits could be created only by turning actual money into the bank—not through loans, as is common practice today. The limitation as to real-estate loans was incorporated into the National Bank Act of 1863.

First Bank of the United States. At the close of the Revolutionary War, there were probably not more than three or four well-established

and sound banks in the United States. Thus the organization of a national institution which should have branches scattered over the country and which should be practically the representative of the Federal Government seemed peculiarly desirable.

Such an institution was created in 1791, upon the recommendation of Alexander Hamilton, the first Secretary of the Treasury, and became known as the "First Bank of the United States." The bank had a capital of $10,000,000, divided into 25,000 shares of $400 each. Of this sum, $8,000,000 was open to subscription by the public, while the other $2,000,000 was subscribed by the United States. The subscriptions to the stock were paid at least one fourth in specie and the balance in Government bonds.

Simple asset-currency bank notes, secured by the general credit of the bank, and legal tender for payment of debts to the United States were authorized to be issued. The liabilities of the bank, except to depositors, were not to exceed the amount of its capital stock. This restriction limited its note issue to an amount not in excess of the capital of the bank. The notes were made receivable for public dues as long as they should continue to be payable in gold and silver. There were no legal reserve requirements against either notes or deposits. The bank was allowed to establish branches wherever the directors saw fit, but only for discount and deposit. It was not permitted to deal in merchandise of any kind, except in the case of forfeited collateral, and was not allowed to hold real estate, though it might lend on mortgage security. The bank was to transact much of the fiscal business of the Government and was given an exclusive national charter for 20 years.

The bank proved to be a great success, since it rendered the currency of the country more stable, supplied much needed banking accommodation, provided a note currency which, on the whole, was satisfactory, and rendered valuable fiscal services to the Government. The bank forced upon many state-chartered banks the obligation of redeeming their circulating notes on demand. Throughout its history, it maintained itself in a strong position. Nevertheless, there was considerable opposition to the bank from the first, on the ground that it was aristocratic and powerful, and this opposition grew as the time came for the expiration of its charter. The opposition was due in part to the fact that 18,000 out of a total of 25,000 of the bank's shares were owned abroad and, therefore, that profits went abroad. The state banks, which had been increasing in number and in influence, became antagonistic because of the competition of the larger bank and the fact that it exercised a regulatory control by refusing to accept the notes of state banks which did not redeem their notes promptly.

The bank's stockholders, of course, were desirous of continuing the institution and, as early as 1808, petitioned for a renewal of its charter. The Government had been well served by the bank; it had made a handsome profit on its stock, besides receiving dividends averaging 8⅜ per cent per annum. The bank occupied a strong situation, as it had on hand about $5,000,000 in specie, while its loans and discounts amounted

to $15,000,000, consisting chiefly of short-term paper. Nevertheless, after a bitter struggle, Congress refused to renew its charter, and the bank went out of existence in 1811.

Second Bank of the United States. This was a most unfortunate time to make a change in the Federal Government's system of banking. As the War of 1812 was on the point of breaking out, the public and the Government more than ever needed the aid of a strong financial institution. The state banks in this period of national crisis proved to be too weak to render substantial aid. In 1814, there was a general suspension of specie payment, and it became impossible for the Government to transfer funds from one part of the country to another for the reason that the notes of the banks of one section were not accepted in other sections. Conditions became so bad that fresh proposals were put forward for the organization of a new United States bank, and Congress finally passed a law in 1816 authorizing the Second United States Bank.

Although it was much larger, the second bank was in most respects like the first. The capital was $35,000,000; one fifth was subscribed by the Government and four fifths by the public. In order to be assured of an exclusive charter for 20 years, the bank paid the Government a bonus of $1,500,000.

The bank was not well managed during the first few years of its existence, but later new managers applied a rigid system of control over the state banks by insisting that they keep their notes redeemed in coin upon presentation. Branches were established here and there as needed, and the note currency issued by the bank became a practically universal circulating medium. Although it carried on various operations that were probably outside the scope of its charters and did not conform strictly to the limitations with respect to methods of issuing circulating notes, the bank was undoubtedly the most powerful and best managed financial institution the country had seen, and its effect was to supply a far higher degree of convenience and efficiency in consummating commercial transactions of all kinds than had ever before been experienced in this country.

The Second United States Bank, however, like its predecessor, fell into difficulties because of political opposition. A re-charter was refused; but the bank obtained a charter for 30 years from the State of Pennsylvania in 1836, thus becoming a state institution and retaining its original capital of $35,000,000. Up to this point, the bank had occupied a sound position for many years, but it now found itself with too large a capital for the more restricted field in which it was compelled to operate and, in 1841, was finally obliged to suspend operations and go into liquidation.

Development of state banking. While the Second Bank of the United States had been running its course, the various states were experimenting with different kinds of banking systems, some successfully and some disastrously. Among the distinct types of banking systems developed during the first half-century of our national life was the so-called "Suffolk system of redemption." The banks had found it difficult to maintain constant and ready redemption of their notes and had observed

that the sounder institutions suffered from the practices of those who were *willing to go as far as they could in evading prompt redemption* and in resorting to more or less questionable methods. According to the principle of Gresham's law, the notes of the weaker banks that did not redeem their notes promptly tended to remain in circulation, while *those of the stronger banks that redeemed on demand* were quickly withdrawn from circulation. The result was a desire to enforce prompt redemption of notes, and this was accomplished by the Suffolk system.

Under this system, the New England banks joined in establishing in Boston a redemption office, which was conducted by the Suffolk Bank, incorporated in Boston in 1818. A substantial number of New England banks joined in a plan whereby each made a permanent deposit with the Suffolk Bank and, in addition, kept on deposit such sums as were needed for the current redemption of their notes. The country banks at first were unwilling to join the system, but were finally obliged to yield and make the required deposit with the Suffolk Bank, which thereafter redeemed their notes at par when presented, charged them up to the issuing banks, and sent the redeemed notes home whenever desired. This was tantamount to the establishment of a clearing house for bank notes. The Suffolk system thus furnished a striking object lesson in the good effects of prompt redemption of bank notes and was very influential in later banking legislation.

In 1838, an act was passed in New York known as the "Free Banking Act." This act authorized any person or group to establish a bank and to issue notes by obtaining a charter from the state comptroller and by depositing with him bonds of the United States, of the State of New York, or of any other state approved by him. Under certain conditions, mortgages could be deposited. Immediately, many people rushed into banking. The demand for the securities eligible for deposit with the comptroller caused prices to rise during the period when the banks were being organized, so that when the banks failed, as some 26 of them (out of a total of 76) did during the years from 1839 to 1843, the bonds held to secure their circulation were sold at a price lower than that at which they had been accepted by the comptroller.

In 1840, the law was amended and strengthened by limiting the securities against which bank notes might be issued to bonds of New York State and the United States. This had the effect of further depressing the price of other bonds held to secure outstanding notes. Notes of the banks which failed during this period were redeemed at an average discount of 20 per cent for those secured by bonds and 25 per cent for those secured by a combination of bonds and real-estate mortgages.

The law, as amended, left little to be desired from the standpoint of security. Losses were reduced to as low as one fortieth of 1 per cent of the average annual circulation. The principle of bond-secured bank notes was adopted by several Western states, including Illinois, Indiana, and Wisconsin. However, these states did not limit the securities pledged as carefully as had New York, and the result was frequently disastrous.

The principle of bond-secured bank notes was incorporated into the National Bank Act of 1863.

The success of the First Bank and of the Second Bank of the United States led to the organization of imitations in the form of a number of state banks modeled on these Federal institutions. The State Bank of Indiana was chartered in 1834 with 10 branches and was granted a monopoly of the banking business in that state. The State Bank of Ohio, established in 1845, combined the safety principles of both bond-secured notes and the so-called "safety fund." In 1842, Louisiana passed a banking act which marked an advance over the laws of the time, inasmuch as the law required a specified percentage of reserve to be held behind deposits. Out of these conflicting systems, there developed a gradual tendency toward better banking conditions and wiser management.

After the discontinuance of the Second Bank of the United States, there ensued a severe panic, starting in 1837, caused in part by unwise banking and the undue extension of credit on improper or inadequate security, especially speculative, unproductive real estate and internal improvements. The result was to warn the banks against repetition of the practices which previously had led to inflation and disaster.

There was a gradual improvement in methods between 1840 and 1860; but the evils of a decentralized, widely diffused, and uncontrolled system of banking, or lack of system, continued to exist. At the opening of the Civil War, there were more than 1,600 kinds of bank notes in circulation. Counterfeits were numerous, and except for voluntary arrangements made by groups of banks among themselves, there was nothing to compel banks to receive the notes of other banks. Redemption facilities were crude and inefficient throughout most of the country. For these and other reasons, there arose a strong feeling in favor of some change in the direction of more powerful central control that would guarantee a safer and more uniform note issue and, at the same time, bring about needed reforms in credit extension.

The national banking system. In 1861, Secretary of the Treasury Chase proposed a national banking system as a means of providing a safe and uniform bank-note currency secured by United States bonds, as well as a market for the bonds of the Government. A bill embodying his ideas was defeated in Congress in 1862. However, on February 25, 1863, the National Bank Act was passed. After a year's trial, it was repealed and superseded by the National Bank Act of June 3, 1864, which removed some of the more outstanding defects disclosed by the year's experiences. In addition to containing the best provisions of the various state banking laws, the act introduced some original features.

The results obtained under the new law were at first discouraging. Up to November 15, 1864, only 584 national banks had been organized. State banks saw no reason for joining the national banking system, since its provisions were much stricter than those of the state laws under which they were operating. It had been thought that the new system would bring about a safe and uniform bank-note currency through the

introduction of national bank notes, but the state banks would not give up their state charters and hence continued to flood the nation with their unsatisfactory note issues. Therefore, in 1865, Congress passed a law taxing state bank notes 10 per cent. Since no institution could afford to pay such a heavy tax on its notes, state bank notes rapidly disappeared from circulation. This tax also had the effect of forcing many state banks into the national banking system.

A market for United States bonds was created by requiring each national bank to purchase and deposit with the Treasurer of the United States bonds to the amount of not less than one third of its paid-in capital stock, and in no case less than $50,000. This provision was later modified in order to permit banks with a capital of $150,000 or less to deposit bonds to the amount of only one fourth of their capital. In 1913, the Federal Reserve Act abolished the requirement that national banks must purchase United States bonds, unless, of course, they desired to issue national bank notes.

Under the terms of the act of 1863, national banks were permitted to issue bank notes secured by a deposit of United States bonds bearing the circulation privilege, but not in excess of the bank's paid-in capital stock. From 1861 to 1900, a deposit of bonds with a market or par value (whichever was the lower) of $100 was required for every $90 worth of notes. In 1900, the law was changed to permit the issuance of notes up to the par value of the bonds, provided the market value of the bonds was not below their par value. If below par value, additional security was required. Uniformity of issue was obtained by making the notes of the same size and design, though the name of each bank appeared on its own issue.

Whether or not national banks issued bank notes was entirely a matter of choice. If notes were issued, United States bonds having the circulation privilege were deposited with the Comptroller of the Currency, who transferred them to the Treasurer of the United States A redemption fund of 5 per cent in lawful money was also deposited. Without listing the various expenses, direct and indirect, attached to the issuance of bank notes, it can be said that a profit of ½ to 1 per cent was commonly made on national bank-note circulation, in addition to the regular return of interest on notes paid to customers in place of other money. The Federal Home Loan Bank Act of July 22, 1932, amended the National Banking Act to permit an increase in the national bank-note circulation. This legislation extended the circulation privilege for a period of 3 years to all bonds of the United States Government bearing interest at 3⅜ per cent or less. On March 9, 1935, the Treasury Department announced a plan for the retirement of the national bank notes. All the 2 per cent bonds bearing the circulation privilege were called for redemption on or before August 1, 1935. The Treasury provided for the redemption by earmarking $646,000,000 of the gold profit from the devaluation of the dollar. This sum was deposited, from time to time, in the Federal Reserve banks in the form of gold certificates, with the Government drawing against the deposit to meet the bond redemption

Thus, with the expiration of the 3-year privilege under the act of July 22, 1932, and the calling for redemption of those bonds carrying the circulation privilege, national banks were deprived of their privilege of issuing bank notes.

A third provision of importance in the National Bank Act was that relating to the minimum capital stock of a national bank. Until 1900, a national bank could not be established with less than $50,000 capital. In that year, however, the minimum was lowered to $25,000, in order to permit the establishment of national banks in small towns where a larger capital would make profitable operation generally impossible. But the Banking Act of 1933 has increased the minimum capital required for newly organized national banks in towns of less than 6,000 population from $25,000 to $50,000. The act has provided also that institutions established in cities with a population of from 6,000 to 50,000 are to have a minimum capitalization of $100,000, while banks organized in communities of more than 50,000 population must be capitalized at least at $200,000.[1] Furthermore, at the time of organization, all banks must have a surplus equal to 20 per cent of their capital. These provisos of the Banking Act of 1933 are designed to strengthen the financial structure of that part of the banking community—the small banks—where failures were most prevalent during the period 1920 to 1933.

The Banking Act of 1935 terminated the double-liability feature of national bank stocks. This latter provision, incorporated in the Banking Act of June 3, 1864, made shareholders of every national banking association liable for all debts of their bank to the extent of the par value of their shareholdings.

Bank-stock shares are usually issued in denominations of $100. But a national bank is permitted to issue its shares in sums of $100 or less if such is provided for in its articles of association.

Another practice approved and further strengthened by the National Bank Act of 1864 was that of requiring a fixed reserve of lawful money behind deposits. The cities of the country were classified as "central reserve cities," or "reserve cities," or as "other cities" (sometimes called "country cities"). New York, Chicago, and St. Louis were placed in the first classification, about 50 of the next largest cities in the second, and all the remaining cities in the third. National banks in the central reserve cities were required to keep all of their reserves on hand, but all other national banks were allowed to deposit part of their reserves with other national banks. Though later amended because of serious defects, this plan of reserve requirements was a notable advance over previous or existing plans or methods.

The National Bank Act stressed the importance of drawing up reports showing the financial condition of all national banks. At first, four sworn reports were required annually. The number was later changed to

[1] A national bank with a capital stock of not less than $100,000 may be established with the approval of the Comptroller of the Currency in the outlying districts of a city of more than 50,000 population, provided the banking laws of the state permit state-chartered banks to be organized with a capital of $100,000 or less.

five, and then to three. In addition, the law subjects national banks to semiannual examinations, or audits, made by representatives of the Comptroller of the Currency

Additional safeguards were thrown around national banks by rigidly limiting and prescribing their lending powers, by fixing the liability of stockholders and directors, and by requiring the banks to confine their operations solely to the banking field Created to function as commercial banking institutions, national banks were not originally permitted to engage in savings-bank business, to make real-estate loans, or to carry on any fiduciary or trust-company activities. The Federal Reserve Act and the McFadden Act, however, removed or modified these and other restrictions

Principal defects of the system. Space does not permit a discussion of the various defects of the National Bank Act that led to the passage, in December, 1913, of the Federal Reserve Act, which, with certain amendments suggested by experience, is the fundamental law of our present banking system The chief objections to the old national banking system are concisely stated in the report of the National Monetary Commission, established by Congress in 1908 to inquire into what changes were necessary or desirable in the monetary system of the United States Of the 17 defects listed, the following were of outstanding importance:

(1) No provision was made for the mobilization and use of the scattered reserves of the country's banks

(2) Antiquated Federal and state laws restricted the use of bank reserves and curtailed the lending power of banks during periods of stress, when reserves should be freely used and credit liberally extended to all deserving customers

(3) Banks lacked the ability to replenish their reserves or increase their lending power to meet unusual demands

(4) The country was hampered by an inelastic currency made up chiefly of bank-note issues, the volume of which was usually dependent upon the amount of United States bonds held by the issuing banks and the price of the bonds, not upon the fluctuating needs of business

(5) Banks were without means of coöperation and deprived of the possibility of joint action in times of stress.

(6) Lack of an established market for agricultural, industrial, and commercial paper led to an unhealthy congestion of lendable funds in great centers, tending to encourage speculation and injurious disturbances to reserves. The United States lacked a broad discount market.

(7) There was a marked lack of equality in credit facilities between different sections of the country.

To this list of defects should be added the fact that, prior to the passage of the Federal Reserve Act, we were largely dependent upon foreign banking institutions in carrying on our commercial dealings with foreign countries This was due to the fact that national banks were not allowed to create bank acceptances, the recognized instrument in all important commercial countries for the use of credit in connection

with export and import transactions. Some private bankers and some state-chartered banks were using acceptances in a rather limited way, but the total volume of such acceptances was not sufficient to justify or make possible an open-acceptance market such as that which has developed in recent years.

Federal Reserve Act. The general purposes of the Federal Reserve Act, as set forth in its title, are as follows:

> An Act to provide for the establishment of Federal Reserve banks, to furnish an elastic currency, to afford means of rediscounting commercial paper, to establish a more effective supervision of banking in the United States, and for other purposes.

The country was divided into 12 Federal Reserve Districts, in each of which was organized a Federal Reserve bank [2] and, subsequently, such branches as have been deemed desirable. Each of the 12 Federal Reserve banks is a separate, independent organization governed by its own board of directors, but the activities of the banks are coördinated through the Board of Governors. The board is composed of 7 members appointed by the President with the advice and consent of the Senate for a period of 14 years. The terms of the members of the board are arranged so that not more than one term will expire in any 2-year period. Furthermore, no member of the board can be reappointed; apparently, the thought being that domination of Federal policy by any one group of men would thereby be avoided. The President of the United States appoints one of the 7 members as chairman of the board for a term of 4 years. A vice-chairman is also chosen to preside in the absence of the chairman. Since the board is to act as a coördinating body and to report a national point of view, the President is directed to select members with "due regard to a fair representation of the financial, agricultural, industrial and commercial interests and geographical divisions of the country." [3] It also stipulated that not more than one member may come from any one Federal Reserve District; moreover, no member may be an officer, director, employee, or stockholder of any banking institution. The Secretary of the Treasury and the Comptroller of the Currency, members of the Federal Reserve Board since its organization, were removed therefrom by the Banking Act of 1935, which provided that their membership was to terminate on February 1, 1936. The more important powers of the board may be summarized briefly as follows:

(1) To examine Federal Reserve banks and member banks, and to require written weekly reports from the reserve banks for publication.

---

[2] The Organization Committee of the Federal Reserve System, composed of the Secretary of the Treasury, the Secretary of Agriculture, and the Comptroller of the Currency, after a careful survey of banking, business, and commercial conditions, named these cities as the locations for the Federal Reserve banks: Boston, New York, Philadelphia Cleveland, Richmond, Atlanta, Chicago, St. Louis, Minneapolis, Kansas City, Dallas, and San Francisco.

[3] Section 10 of the Federal Reserve Act as amended.

(2) To permit, or, on an affirmative vote of at least 5 members of the Board of Governors, to require Federal Reserve banks to rediscount the discounted paper of other Federal Reserve banks at rates of interest to be fixed by the Board of Governors

(3) To suspend for a period not exceeding 30 days and, from time to time, to renew such suspension for periods not exceeding 15 days, any reserve requirement specified in the act, subject, however, to certain conditions.

(4) To supervise and regulate through the bureau, under the charge of the Comptroller of the Currency, the issue and retirement of Federal Reserve notes, and to prescribe rules and regulations under which such notes may be delivered by the Comptroller to the Federal Reserve agents applying therefor.

(5) To add to the number of cities classified as reserve and central reserve cities, or to reclassify existing reserve and central reserve cities, or to terminate their designation as such

(6) To suspend or remove any officer or director of any Federal Reserve bank, the cause of such removal to be forthwith communicated in writing by the Board of Governors to the removed officer or director and to the bank.

(7) To require doubtful or worthless assets held by Federal Reserve banks to be charged off.

(8) To suspend for the violation of any provision of the act the operations of any Federal Reserve bank, to take possession thereof, administer the same during the period of suspension, and, when deemed advisable, to liquidate or reorganize such bank.

(9) To require bonds of Federal Reserve agents and to make necessary regulations for the safeguarding of all collateral bonds, Federal Reserve notes, money, or property of any kind deposited in the hands of agents.

(10) To exercise general supervision over Federal Reserve banks.

(11) To permit or require the Federal Reserve banks to establish or close down branch banks in order to meet fully the credit requirements of all sections of a Reserve district.[4]

(12) To grant by special permit to national banks, under the provisions of the act, the right to exercise those fiduciary powers which state banks, trust companies, or other corporations which come into competition with national banks are permitted to exercise under the laws of the state in which the national bank is located.

(13) To employ attorneys, experts, assistants, clerks, and others to conduct the necessary business of the board.

(14) To control more completely open-market operations of the Federal Reserve System through the Federal Open Market Committee, 7 of whose 12 members consist of the Board of Governors.

(15) To supervise all transactions and regulations between any Federal Reserve bank and foreign banks.

[4] In accordance with this authority, 25 branches and 2 agencies have been established.

(16) To remove an official or director of a member bank who violated the banking law or who engaged in unsound bank practices, notwithstanding official warning.

(17) To limit the rate of interest which member banks may pay on time deposits.

(18) To control excessive speculation through the establishment of margin requirements.[5]

The act also made provision for a Federal Advisory Council composed of 12 members, one from each Federal Reserve district, chosen annually by the board of directors of the Federal Reserve bank of the district The purpose of the council is to give the Board of Governors the benefit of its advice on the operation of the system and to apprise it of local conditions throughout the country.

Each Federal Reserve bank is chartered for an indeterminate period and is owned by the member banks of its district through subscriptions to its stock to the amount of 6 per cent of each member bank's capital and surplus. To date, only one half of the subscription has been called. In the event that a member bank readjusts its capital and surplus, its subscription to Federal Reserve bank stock is modified correspondingly. The stockholders are entitled to a cumulative dividend of 6 per cent per annum, while net earnings of the reserve banks over and above the required dividend are placed in a surplus fund.[6]

Membership in the Federal Reserve System is required of national banks, while state banks and trust companies—including mutual savings[7] and Morris Plan banks—may join the Federal Reserve System upon compliance with certain conditions which place them on an equal footing with national banks. Private banks may not become members of the Federal Reserve System.

Each of the 12 Federal Reserve banks is governed independently by a directorate of 9 members. These officials, in office for 3 years, are designated as Class A, B, and C directors. Class A directors are selected by the member banks to represent them; Class B directors, also chosen by the member banks, represent the business interests of the district. They must be active participants in business or agriculture and must not be officers, directors, or employees of a bank. In order to insure adequate representation for the banks of varying size, the law provides that the banks of each district shall be divided into three groups—large, intermediate, and small. Each size classification elects one Class A and one Class B director. Three Class C directors

[5] In order to make effective the board's regulations, brokers and dealers may borrow only from member banks or from such nonmember banks as agree to comply with these regulations.

[6] The Banking Act of 1933 called for the 12 Federal Reserve banks to subscribe to the stock of the Federal Deposit Insurance Corporation to the amount of one half of their surplus At that time, the surplus amounted to $139 300,000

[7] A mutual savings bank is eligible for membership if its surplus and undivided profits are not less than the amount of capital required of a national bank located in the same place and if it subscribes to the capital stock of a Federal Reserve bank in an amount equal to six tenths of 1 per cent of its total deposit liabilities.

are chosen by the Board of Governors. They must be residents of the district and without any bank affiliation in the capacity of officer, director, employee, or stockholder. The chairman of the Board of Directors of each Federal Reserve bank is chosen from the Class C appointees; moreover, he acts also as the Federal Reserve agent and as the board's official representative in the local district. However, the top ranking officer of each Federal Reserve bank is the president, who is appointed by the Board of Directors for a period of 5 years with the approval of the Board of Governors

The Federal Open Market Committee, consisting of the Board of Governors and 5 members chosen annually by the Federal Reserve banks, directs the so-called "open-market operations." This committee controls a very powerful instrument of credit policy.

Operation of the Federal Reserve System. The underlying thought of the Federal Reserve System is to strengthen the existing banking system and to enable it to supply the current needs of business more adequately. To accomplish this, it was vested with broad and far-reaching powers. For one thing, all legal reserves of member banks must be deposited with the Federal Reserve banks The minimum reserve requirements vary, depending on the location of the bank The institutions in the central reserve cities, New York and Chicago, are required to maintain minimum reserves of 13 per cent against demand deposits. The banks in the reserve cities, 59 in number, are called upon to hold reserves of 10 per cent against their demand deposits, while all other banks, termed "country banks," must have a minimum reserve balance with the Federal Reserve banks of 7 per cent against their demand deposits. All members must keep a reserve of 3 per cent against their time deposits. The Banking Act of 1935 granted the Board of Governors the power to raise reserve requirements by 100 per cent.[8] By increasing the reserve requirements, the member banks are deprived of some lending power, and so a credit-restriction policy may be pursued through this credit-control weapon. On the other hand, a reduction of reserve requirements from any point above the minimum balances required quite obviously increases the loanable funds of the banking structure and thereby encourages an easy money policy.

Credit control may also be exercised through the discount-rate policy. The discount rate is the rate charged member banks for notes which they discount at reserve banks The discountable notes consist of eligible commercial paper—such as promissory notes, trade acceptances, bank acceptances, and so forth—resulting from the financing of working-capital requirements of business and agriculture, or the member

[8] At the time of writing, April, 1940, the reserve requirements are the following:

	Reserves Required Against	
	Demand Deposits	*Time Deposits*
Central Reserve City Banks	22¾%	5%
Reserve City Banks........	17½	5
Country Banks....	12	5

banks own promissory notes secured by United States Government obligations, or paper eligible for discount. The business paper may have a maturity not exceeding 90 days, while agricultural paper may have a maturity of 9 months. If the collateral securing a member-bank note consists of eligible commercial paper, the advance may run for 90 days; but if the security consists of United States Government debt, the advance may be for a period not in excess of 15 days. Another form of advance may be made by a Federal Reserve bank, provided the regulations of the Board of Governors are complied with; thus, the reserve bank may make advances to members for a period of not more than 4 months on the basis of satisfactory collateral which is not eligible. However, a penalty rate is imposed upon such advances by a charge of at least one half of 1 per cent higher than the highest rate in effect at the reserve bank.

The rates of discount at each Federal Reserve bank are fixed by the Federal Reserve banks, "subject to review and determination of the Board of Governors."

Through an increase in the discount rates, the reserve banks can discourage borrowing and so impose a condition of tight money upon the business world. A reduction of discount rates is intended to encourage business by making it less expensive for the member banks to obtain funds at the Federal Reserve banks; and, in turn, it is hoped that the banking community will pass on the lower costs of borrowing to the business public.

The discount process may result in an increased amount of Federal Reserve notes in circulation. A member bank, by discounting its own or its customers promissory notes, secures the necessary funds with which to meet heavy cash withdrawals by the business public. The reserve bank will pay over the amount of the discount either in the form of cash paid out of reserves or in Federal Reserve notes. On the other hand, when the business community finds itself with an excessive supply of till money, cash is deposited with the commercial banks, and the result is an excess of funds in the bank vaults. The unnecessary cash on hand is usually turned over to the reserve banks; and, to the extent that it consists of Federal Reserve notes, the Reserve bank's liability for its notes in circulation is reduced. This arrangement provides for an elastic note issue responsive to the needs of business. However, if the funds deposited in the Federal Reserve bank consist of other kinds of money than Federal Reserve notes, the result is merely an increase in the member banks' reserves.

The open-market operations of the Federal Reserve banks provide still another method of credit control. These activities, as mentioned above, are controlled by the Federal Open Market Committee, with whose rulings all reserve banks must comply. The system's open-market operations may be in securities of the United States Government or those fully guaranteed thereby; cable transfers; eligible foreign and domestic bills of exchange; bankers' and trade acceptances; the obligations of states, municipalities, and other political subdivision if they

mature within 6 months; and gold coin and bullion, in so far as permitted under the Gold Reserve Act of 1934. For all practical purposes, the open-market operations have been largely in United States Government securities and bankers' acceptances. A buying program by the Federal Open Market Committee will increase member-bank reserve balances and thereby encourage low money rates, while the reverse procedure—the sale of open-market holdings—will reduce the size of reserve balances and so make for a tighter money market.

The misuse of Federal Reserve and member-bank credit for speculative purposes and the deflation of 1929 to 1933 led to the passage of the Banking Act of 1933, which increased the Federal Reserve System's control of speculative credit. The Board of Governors was directed to keep itself informed of the undue use of credit for the speculative carrying of or trading in real estate, securities, or commodities, and the Federal Reserve banks were ordered to consider such information in granting credit. Furthermore, the board was ordered to establish for each Federal Reserve district the percentage of individual bank capital and surplus that might be represented by loans on stock or bond collateral. Moreover, 90-day advances by reserve banks on member-bank notes secured by eligible paper are to become due immediately if collateral loans are increased in spite of an official warning to the contrary. In addition, the board was given the power to suspend a member bank from the use of Federal Reserve credit facilities if it continued to make unduly great speculative loans notwithstanding official warnings. Finally, the Banking Act of 1933 prohibited member banks from acting as agent for nonbanking interests in the granting of collateral loans to brokers and dealers in investment securities. The Securities and Exchange Act of 1934, providing for Government regulation of security trading, vested the Board of Governors with the power to establish margin requirements on brokers' loans. This legislation also established the principle that brokers and dealers may borrow only from member banks and from such nonmember banks as comply with the board's regulations.

In 1934, the Federal Reserve banks were given the power to make direct loans to business for working-capital purposes whenever an established industry or commercial business was unable to obtain financial assistance from the usual credit sources. Loans resulting from the exercise of this power can not be outstanding more than 5 years.

Mention must be made also of the nation-wide clearing and collection system established by the Federal Reserve organization. Each reserve bank serves as a central clearing house and collection agency for the member banks within its district. Moreover, the Interdistrict Settlement Fund, under the jurisdiction of the Board of Governors, establishes a national clearing arrangement.

Lastly, the reserve banks act as a fiscal agency for the United States Government. They hold Government revenues on deposit and disburse Federal funds. They also act as the distributors of the coin and currency of the country; new issues of Treasury currency are ordinarily

placed with these central banks. Again, the reserve banks handle the sale of Government securities, which have reached large proportions in the depression years.[9]

Advantages of the Federal Reserve System. The principal benefits which have accrued to banks and to the business interests of the country are set forth below. This brief summary, though considerably curtailed, also serves the purpose of throwing additional light, indirectly, upon the Federal Reserve banks' activities.

Economy. By the pooling of the reserves of all member banks of each district in the Federal Reserve bank of the district and by the practical merging of these 12 reserve funds into one inclusive fund through the discounting privileges of Federal Reserve banks, great economies have been effected Not only have legal reserve requirements been reduced, but banks in general have been enabled to operate successfully and safely with far smaller actual reserves.

Establishment of a rediscount market. With the capital paid in by member banks supplemented by earned surplus and with the reserve deposits of member banks multiplied by the power of the Federal Reserve banks to issue Federal Reserve notes against 60 per cent of eligible paper and 40 per cent of gold certificates, Federal Reserve banks have been enabled to make advances to member banks exceeding by many times the total amounts borrowed by all banks at any previous period, at rates ranging from 1 per cent to 6 per cent and, in the most extreme cases, not exceeding 7 per cent.

Furnishing of an elastic currency. Federal Reserve notes, which are direct obligations of the United States Government and the issuing Reserve banks, are loaned without interest to Federal Reserve banks, at the discretion of the Board of Governors, upon the deposit of the required security with the Federal Reserve agent. The volume of Federal Reserve notes has responded promptly and fully to the demands of business, increasing when more currency is needed or automatically decreasing when the need has passed.

Establishment of a par-collection system. In 1916, the present par-collection system of the Federal Reserve banks was established. Beginning with all member banks and approximately an equal number of nonmember banks, the system has grown until it embraces most of the banks of the country. By this system, not only has the payment of exchange been abolished with respect to all banks embraced in the system, but the old methods of circuitous routing have been done away with. This has effected great economies. In handling checks drawn upon member banks and nonmember par banks, the Federal Reserve banks have been able to render to the business interests of the country an exceedingly valuable service from a credit standpoint.

More effective supervision of banking. Member banks, particularly

[9] The Banking Act of 1935 prohibits the reserve banks from buying obligations of the United States Government directly from the Treasury It was believed that the Treasury would then be forced to rely entirely upon the open market and would thus be more careful in its creation of debt.

those that discount freely with their Federal Reserve banks, are in constant and intimate contact with the Federal Reserve bank management. As a result, in many cases, mistaken policies have been detected before trouble has ensued, and in other cases, member banks have been enabled to avoid the serious consequences which would have resulted in the absence of such friendly and able assistance.

The McFadden Bill. The McFadden Bill, approved by Congress in 1927, had for its purpose the enlarging of the charter powers of national banks, so that they might meet the competition of state banks on a more nearly equal basis. Some of its more important provisions are:

(1) It permits the direct consolidation of national and state banks.

(2) It provides indeterminate charters for national banks, so that they may exercise more fully trust functions permitted under the terms of the Federal Reserve Act.

(3) It legalizes the practice of national banks of buying and selling investment securities, under such a definition of the term "investment securities" as may be prescribed by the Comptroller of the Currency.

(4) It permits national banks to acquire and hold real property, even though not intended for immediate use, in order that they may make reasonable and provident provision for future expansion. It also permits national banks to make loans on improved real estate, subject to certain restrictions. The Banking Act of 1935 also liberalized the restriction upon real-estate loans. The aggregate of such loans is fixed by this law at the amount of the lending bank's capital and surplus or 60 per cent of its time deposits, whichever is the higher.

(5) It establishes the policy of Congress in the matter of branch banking for national banks by legalizing branches of such banks in lawful operation on February 25, 1927 (the date of the approval of the act). The act further provides that branches of national or state banks may be retained if a state bank is hereafter converted into or consolidated with a national bank, or if two or more banks are consolidated.

Federal Farm Loan Act. The Federal Farm Loan Act, which became effective in July, 1916, provided for the establishment of a bureau in the Treasury Department to be known as the "Federal Farm Loan Bureau" and to be supervised by a Federal Farm Loan Board. It further made provision for the creation of 12 Federal Land Banks and permitted the establishment of any number of Joint-Stock Land Banks for the purpose of making loans at reasonable rates, for long periods of time, on farm lands. The country was to be divided into 12 Farm Loan Districts, in each of which would be established a Federal Land Bank with a subscribed capital stock of not less than $750,000. Banks were established in Springfield (Massachusetts), Baltimore, Columbia (South Carolina), Louisville, New Orleans, St. Louis, St. Paul, Omaha, Wichita, Houston, Spokane, and Berkeley (California). Each bank is permitted to establish branches in its own district.

Ordinarily, the Federal Land Banks lend to farmers, not directly, but indirectly through National Farm Loan Associations which, according

to the act, may be formed by at least 10 farmers in the district, each of whom desires to borrow on his land or on the improvements thereon. However, subsequent amendments permitted direct loans to farmers on the security of first mortgages on farm land. After an association has been chartered, loans up to $50,000 may be made to any member, but applications for loans of more than $25,000 must be submitted to the Land Bank Commissioner for approval.[10] Loans may be made up to 50 per cent of the appraised normal value of the land and up to 20 per cent of the appraised value of the permanent insured improvements, but not in excess of the limitation of $50,000 to one person. Money may be borrowed only for approved purposes—such as the purchase of land for agricultural uses; the purchase of equipment, fertilizers, and livestock for the reasonable operation of the mortgaged farm; the construction of buildings and improvements on farm lands; the payment of indebtedness of an eligible borrower if increased prior to January 1, 1937; the payment of other debts incurred at any time for agricultural purposes; and the provision of funds for general farm uses to owners of mortgaged land. The Farm Credits Act of 1935 permits Federal Land Bank loans under certain conditions to corporations engaged in raising livestock

Charters are issued to proposed associations by the Federal Land Bank of the district. Each prospective borrower must subscribe for an amount of the capital stock of his association equal to 5 per cent of his loan. The money thus subscribed is used for the purchase of an equal amount of stock in the Federal Land Bank of the district. The stock is held for the association by the bank, which then lends the money desired to the farmer through his association. The act made provision for the retirement of the original stock of the land banks owned by the Government and others in such a manner that, eventually, the banks would be owned completely by the National Farm Loan Associations, which in turn are owned by farmer borrowers.

Government money and Government enterprise established the Federal Land Banks, but in order to offer an opportunity for private enterprise in the same field, the Farm Loan Act provided for the establishment of Joint-Stock Land Banks. Minimum capital requirements were $250,000, which might be subscribed by at least 10 stockholders. Loans were made directly to the borrowers and might run from 5 to 40 years, secured by first mortgages only and limited to 50 per cent of the appraised value of the land and 20 per cent of the appraised value of the improvements. The banks operated under the jurisdiction of the Federal Farm Loan Board. The Emergency Farm Mortgage Act of 1933, however, called for the orderly liquidation of existing Joint-Stock Land Banks, which is now being done. This latter act also provided for a fund of $200,000,000 with which the Land Bank Commissioner could meet a demand for additional farm-mortgage credit.

[10] The Land Bank Commissioner is responsible for the supervision and regulation of the Federal Land Banks and National Farm Loan Associations. He is an official of the Farm Credit Administration, established in 1933.

The Agricultural Credits Act of 1923 provided for the establishment of 12 Federal Intermediate Credit Banks The capital stock of each credit bank was to be subscribed by the United States Government. In 1934, the Farm Credit Administration, under the authority of the Federal Farm Mortgage Act, increased the capitalization of the banks. These institutions were organized to make loans to or rediscount paper for such organizations as coöperative marketing associations, state and national banks, agricultural credit corporations, and incorporated livestock loan companies.

The Economic Significance of Banking to Our Present Industrial Development

Banking and finance, by supplying to commerce and industry immediately available purchasing power in the form of credits, furnish them with the means to make enlarged productive operations effective in the present, for which otherwise the necessary capital could only be built up over a period and brought into play in the future. Generally speaking, they do this in two ways: through long-time, or investment, credit; and through short-term, or commercial, credit. Through investment credits, funds are supplied promptly to industrial enterprise to expand its capital equipment, such as plant and machinery, in order to enable it to enlarge its operations and earnings, retiring its borrowings gradually over a period of future years. Through short-term credits, or commercial loans, additional working capital for the purchase of raw materials and labor is supplied, enabling industry and trade to expand current operations in keeping with present business conditions, normally liquidating these borrowings out of the proceeds of each cycle of production or turnover of goods. This latter form of credit is the distinct service of commercial banking to business and industry, while the former type of credits—that is, investments—are handled more properly by investment houses. However, commercial banks, trust companies, and savings banks, through their investment accounts for themselves and customers, constitute a major part of the market for investment issues. Prior to 1933, commercial banks frequently organized investment affiliates which supplied investment credits However, the Banking Act of 1933 ordered the divorce of the investment affiliates by June 16, 1934, 1 year from the date of passage of the act. It was believed that commercial bankers who were charged with the responsibility of investing depositors' money should not at the same time engage in the underwriting and selling of securities which might lead to the improper use of depositors' funds.

In addition to the afore-mentioned credit functions, banks provide important services to commerce and industry as depositories of their current working and surplus funds, performing in this connection a vast amount of technical, mechanical, and bookkeeping detail, and materially facilitating the operations of business along such channels as the interchange of funds by means of checks, the making up of payroll accounts,

the placing of surplus or temporarily idle funds in investments for the benefit of their depositors, or in interest-bearing accounts in the form of time deposits or certificates of deposit.

Effect of collateral borrowing on banks. During the period of stock speculation preceding the depression of the 1930's, a considerable adverse effect upon banking conditions was exerted by the extremes to which loans on collateral, either from the banks or through the assistance of the banks, were carried. On a very extensive scale, individual customers of banks, who formerly confined their borrowings from them either to unsecured commercial loans directly connected with the productive operations of their businesses or to loans secured by stocks or bonds as collateral for the purpose of augmenting funds to be employed in their own proper business, created an abnormal volume of collateral loans from the banks for the purpose of stock speculation or investment beyond the strict scope of their own business operations. When the collapse in security prices occurred, widespread losses left many of these borrowers unable to repay their bank loans, and it was often necessary for the banks to take over the collateral securing them. The rapid depreciation of this collateral frequently left the banks with insufficient security. By this indirect process, banks very generally came into possession of a large volume of undesirable investments whose liquidation was difficult except at a loss. Also, during the boom, many corporations, through the sale of securities, created large cash balances, which they instructed the banks to loan out directly for them in the form of call, or time, loans secured by stock-exchange collateral, thereby creating a vast volume of credit out of control of the banks, which was employed by speculative borrowers and contributed to the inflation that came to an end in the stock-market collapse of 1929. This "great invisible banking system," as it was called, hurriedly withdrew these loans from the call-money market during the panic, adding to the enforced liquidation of the speculative accounts it had been supporting. In this emergency, a great part of this speculative credit structure was taken over by the banks, thus preventing a far greater catastrophe than actually occurred. The situation was that a large volume of the speculative securities bought on margin were carried by means of the loans from this "invisible banking system," which became panic-stricken at the drop in security values that undermined the security of the loans and precipitately called them, forcing the borrowers to throw securities overboard at almost any price in order to meet these demands. The banks, however, by concerted action replaced, so far as possible, this volume of credit that was drawn out of the market and materially relieved conditions by permitting a liquidation of the speculative situation by far less disorderly steps than otherwise would have been possible. The Banking Act of 1933 contained a provision designed to minimize the functions of the "invisible banking system." Section 11 (a) prohibited member banks from acting as the medium through which a nonbanking corporation could make loans to brokers or dealers in securities on the basis of such collateral.

Effects of business panics on banks. Banks are particularly vulnerable to the effects of business panics. As was shown in the foregoing discussion, they had a very difficult function to perform in connection with the liquidation of the speculative stock-market boom which began in 1929, both through extending support to the call-money market under the difficult conditions of the emergency and also by coming into possession of a vast volume of depreciated collateral security on which they had extended loans to their own customers. Another source of danger to banks in a period of panic is the possibility of runs by depositors. A bank is never wholly liquid to the full extent of its demand deposits, which are employed in loans and in investments to create the earning assets of the bank. A bank's cash reserves are ordinarily sufficient only to meet normal withdrawals of deposits. In times of panic, when rumors fly regarding the condition of all financial institutions, withdrawals frequently become so rapid and insistent that a bank cannot meet them out of its cash reserves, the maturities of its loans, or through the disposal of its investment assets. Under such circumstances, many a bank is forced to close its doors, even though its assets are more than sufficient to meet all its liabilities, in order to gain time to realize cash on its assets in an orderly way. As a matter of fact, in a great majority of cases, the liabilities of closed banks are finally paid in full or almost in full, and losses to depositors are caused by their own destructive urgency, rather than by any basic weakness in their bank. Other effects of panics and business depressions upon banks are the curtailment in the volume of commercial credit, an increase in losses on loans, and a drop of values of the securities in which their funds are invested.

Banking in the Depression

The general economic liquidation during the depression was accompanied by a rapid increase in the number of bank failures which not only exerted deflationary influences but also created a strong fear and distrust of the banking and financial community Hoarding of currency became pronounced in the latter part of 1930 and continued in 1931 and 1932, when the chaotic international financial situation contributed to the general confusion. Particularly damaging to monetary and banking stability was England's abandonment of the gold standard in September, 1931, whereupon the outflow of gold increased markedly.

In order to deal with the demoralized banking situation, President Hoover, with the coöperation of the banking community, organized on October 13, 1931, the National Credit Corporation. This agency was intended to enable banks to borrow on assets ineligible for discount at the Federal Reserve banks. The National Credit Corporation was not Governmentally financed but secured its funds by the issuance of gold notes which each bank was asked to subscribe to up to 2 per cent of its net demand and time deposits. But the corporation was unable to deal adequately with the bank panic. The result was the organization by the Government of the Reconstruction Finance Corporation, on January 22,

1932. This corporation was authorized to grant loans to all classes of banks, to railroads, and to farmers upon adequate security. The Government attempted to ease credit further by the passage of the Glass-Steagall Bill, on February 27, 1932. This legislation temporarily permitted member banks to borrow from the Federal Reserve banks on other assets when lacking eligible paper, while Federal Reserve banks were enabled to use United States Government obligations as collateral for Federal Reserve notes. This latter proviso increased the "free gold" in the Federal Reserve System, which theretofore had been required to cover the Federal Reserve notes in circulation.

Notwithstanding these emergency measures, the business and financial situation was not improved, and a spreading fear gripped the American economy. The result was a growing number of state-wide bank holidays beginning in February, 1932, which culminated finally in the national banking holiday of March, 1933. When, in the latter part of March of that year, the banking system was operating at approximately normal, only some 12,800 banks of the 18,000 in operation prior to the bank holiday were doing business on an unrestricted basis.

The problem of the Government was then one of financial reconstruction. This task, initiated with the passage, on June 16, of the Banking Act of 1933, had as one of its most significant features the establishment of the Federal Deposit Insurance Corporation, whose setup, however, was modified by the Banking Act of 1935. This step was intended to rebuild public confidence in the banking structure by providing for total or partial guaranty of bank deposits. The maximum insured deposit of any one depositor is fixed at $5,000. The funds of the corporation are obtained from capital-stock subscription, assessments levied on the insured banks, and earnings on investments. All of the stock of the corporation is owned by the United States Government and the Federal Reserve banks, the Government subscribing $150,000,000 and the Federal Reserve banks $139,000,000. Insured banks are required to pay an assessment of one twelfth of 1 per cent of their total deposits. The corporation has the power to borrow up to three times its capital stock and the payment of the assessments upon insured banks for the year 1936. All members of the Federal Reserve System must become members of the Federal Deposit Insurance Corporation, while nonmember banks may become members upon compliance with certain specified standards. It is further stipulated that, after July 1, 1942, commercial banks with average deposits of $1,000,000 or more must become members of the Federal Reserve System if they wish to maintain their status as insured banks. The Federal Deposit Insurance Corporation may, after due notice and a hearing, terminate the membership of any bank that has either violated the law or engaged in unsound practices.

The Banking Industry of Today in the United States

On June 30, 1938, there were 15,341 banks of all kinds in the United States, with aggregate resources of $68,302,896,000. The total capital ac-

count of these banks amounted to $8,181,969,000; their total deposits, $59,379,550,000; and their loans and investments, $47,645,960,000. Banking houses, furniture, and fixtures were valued at $1,325,718,000.

Modern banking institutions classified. When the above figures were made, banks were divided into the following classes: national banks, which are fundamentally commercial banks and are chartered by the Federal Government, numbering 5,248; commercial banks, including loan and trust companies and stock savings banks, chartered by the various states, numbering 9,458; mutual savings banks, chartered by or incorporated in the various states, numbering 562; and private banks, officially reporting to the state authorities, numbering 73. A commercial bank receives deposits subject to check and extends short-time loans and discounts, ordinarily running for 60 to 90 days, to assist the current operation of trade and industry. A trust company engages in commercial banking and, more characteristically, in fiduciary services, such as those of the executor and the trustee of estates, living and postmortem trusts, investment advice and management, and many other matters Savings banks accept passbook, interest-bearing deposits primarily for the purpose of helping those of modest means to accumulate sums below investment volumes. Private banks engage in commercial and investment transactions.

Functions and activities of American banks. Although American banks are divided into the general classes listed above, there has been a considerable blurring out of the distinction between them by reason of the fact that the commercial banks, both state and national, have extensively developed in their organizations trust and savings departments, while the trust companies also perform a large volume of commercial banking In fact, under the roof of a great modern bank or trust company, it is possible to obtain virtually all types of financial service, including savings accounts, personal checking accounts, commercial borrowing accounts, investment advice, and coöperation and trust service in all of its various scope.

Internal organization of a typical banking institution. Since banks in the United States vary greatly in size and character, the internal organization differs widely. A small country bank with capital of $10,000 will frequently consist, in the organization of its personnel, merely of a president, who often is a local businessman controlling the bank but not engaged in its active administration; a cashier, who is the active executive; and possibly two or three clerks. Other somewhat larger banks may have an equally inactive president with an active vice-president in charge, and under him the cashier and clerks. As the banks increase in size, the president will become the active administrative officer, with one or more vice-presidents under him, and with a cashier, assistant cashier, and a clerical force in keeping with the volume of business of the particular bank. A large city bank will have a president, perhaps 5 to 10 or even a score of vice-presidents, an auditor, a cashier, a corps of 10 or 20 assistant cashiers, and possibly 1,000 clerks. In a great metropolitan city bank, with its capital funds running upward of $200,000,000 and

its total deposits amounting to more than $2,000,000,000, the internal structure will become very complex. Frequently, these great banks have been built up through mergers, with the result that a number of senior officers, such as presidents and chairmen of boards, have to be taken care of in the organization of the resulting institution. As a consequence of

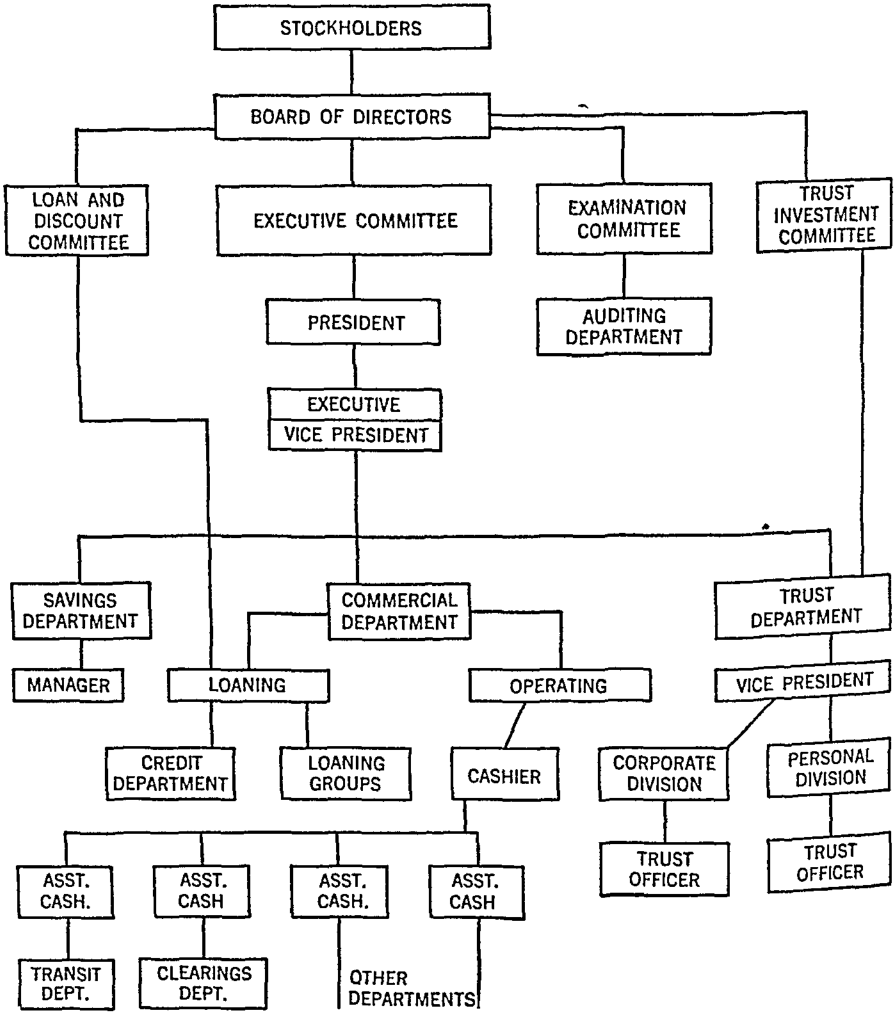


Fig 1. Bank organization chart.

an operation of this kind, we sometimes find a bank manned by a chairman of the board, a vice-chairman of the board, a chairman of the finance committee, a chairman of the advisory committee, the president of the bank, and 30 or 40 vice-presidents, while the lower personnel below the class of cashier and assistant cashiers will sometimes run to 2,000 or 3,000 employees. A bank of this type will be highly departmentalized. A

typical chart of the internal control of a bank is shown in Figure 1.[11]

Branch banking. Branch banking has long furnished banking in the United States with its most mixed and controversial subject. In all, 19 states permit state-wide branch banking; 17 states permit branch banking within limited areas; and only 9 states prohibit branch banking, with 4 states having no legislation regarding this matter. National banks are permitted, with the approval of the Comptroller of the Currency, to establish branches within the various states in which they are located to the same extent to which state laws permit state-chartered banks to organize such branches. On December 31, 1938, 917 banks operated 3,440 branches. Since there were on that day 15,194 banks altogether, it is quite obvious that less than 10 per cent of the banks in the country were branch-operating banks. The great majority of branch-operating banks operate only 2 or 3 suboffices, but there are many instances of banks with 25, 50, or more branches. This type of banking has developed preponderantly in a few great cities but is not prevalent in the rural districts.

In some of these rural districts, what has been called an "indirect" form of branch banking has been developed in the form of group banking—that is, an organization in which a number of separately chartered banks are owned or controlled through the medium of a corporation, business trust, association, or other similar organization. The *Federal Reserve Bulletin* of February, 1938, reported that, on December 31, 1936, there were 52 independent group systems controlling 479 constituent banks. Some of these group organizations included close to 100 individual institutions under the control of a large city banking group through a holding company. A number of these systems radiated into a number of adjoining states. Recent years have witnessed the dissolution of many group systems because of the suspension of the constituent banks, the insolvency of the holding companies, or the consolidation of the group banks which were then operated as branches of one key bank in the group.

Until very recently, banking opinion was preponderantly opposed to branch banking In 1937, the American Bankers Association put itself on record as favoring the preservation and continuance of the dual banking system. It expressed the belief that the system of unit banks was particularly adapted to the diversified community life of the United States, but since various states had authorized the establishment of branch banks, it held that national banks should enjoy equality with state banks having branch-banking privileges within such states. The association also expressed itself as opposed to the establishment of branch-banking privileges across state lines. In 1938 and 1939, the American Bankers Association reaffirmed the action taken in 1937.

---

[11] Taken from the volume *Bank Organization and Operation* by George D. Bushnell of the American National Bank and Trust Company of Chicago, Illinois, published by the American Institute of Banking of the American Bankers Association, for use in its instruction classes for bank workers

Methods of financing a bank. Banks ordinarily start as relatively modest institutions, and their financing is less ostentatious, as a rule, than that of industrial or other business concerns. When a community's growth arrives at a point requiring a bank or additional banking facilities over those already operating, local businessmen organize and promote a new institution, obtaining subscriptions to the necessary capital through personal solicitations. In some states, the minimum capital for organizing a bank is as low as $10,000 for a small village, with a rising scale for larger places, while the minimum for a national bank any place in the United States is $50,000. Generally, the par value of bank stock is $100. When the requisite capital funds are subscribed, a charter may be obtained from the proper authorities upon satisfactory proof that the new bank is needed and that those proposing it are proper persons to organize and operate a bank. Ordinarily, the directors are chosen from among prominent local businessmen who have subscribed to the stock of the bank, in order to tie up its operations with the business interests of the community.

Financing the expansion of a bank is generally carried out in two ways. The most frequent method is through building up surplus out of earnings. Conservative bank management will aim to increase surplus until it equals capital and will always keep capital funds on the basis of about $1 for each $10 of deposits. The second method is by means of subscriptions for an increased capital stock or a subscribed surplus among existing stockholders, but it is not ordinary practice to make public flotations of bank stock. In some cases, however, in order to increase the public interest in a bank in a community, bank stocks have been reduced to a par value of $25 and offered to the general public on the theory that this would increase community loyalty and good will in the institution. In New York City, the stocks of many of the large banks were listed and traded in on the New York Stock Exchange, but when speculation in these stocks in the stock boom ending in the fall of 1929 became active, the management of several of these banks asked that their stocks be removed from the lists in order to take them out of the speculative limelight.

The financing of the great metropolitan banks, some of them with capital funds now amounting to over $100,000,000, has been a matter of evolution rather than of a single or series of public-investment operations. These great banks, for the most part, started as relatively modest institutions and have grown to their present size through long series of amalgamations, mergers, and absorptions involving other institutions; and the major financial problems involved in their capital structure were those connected with working out a satisfactory interchange of stock between the collaborating institutions.

Possible Future of American Banking

The evolution of American banking seems to be along the line of creating fewer but larger banking units. The failures of recent years have

been chiefly among small banks in the country districts, especially at outlying points, with the result that banking has tended to become more concentrated in the larger centers, which are now easily available over relatively large areas by virtue of good roads and the all-pervading prevalence of automobiles. In the large cities as well, the consolidation movement among banks has been rapid, and statistics show that the deposits of the theoretical average bank, taking the country as a whole, has increased notably in recent years.

It is frequently prophesied that the spread of multiple banking, either in the form of branch-bank organization or group systems, will still further concentrate the control of the nation's banking facilities into a relatively few great regional groups. The general economic setback suffered by the country during 1929 and the following 10 years, however, has served to bring to a relative standstill many marked changes that were going on at a rapid pace in the various financial fields.

One marked movement in the banking field that has shown no signs of slowing down is that aimed at bringing about a higher average of scientific banking intelligence by means of education. More and more have bankers realized that theirs is an economic activity susceptible to a large degree to scientific formulation. The most extensive expression of this is through the numerous divisions of the American Institute of Banking and the Graduate School of Banking conducted annually at Rutgers University. These organizations are the educational sections of the American Bankers Association. The American Institute of Banking conducts some 248 banking schools and 107 study groups throughout the country, with a total student body among working bank people in the neighborhood of 41,000. Virtually all large city banks encourage their employees to take the courses presented by these schools and, in most cases, bear part or all of the necessary expenses, while in a few instances, banks make educational effort of this kind a part of the contract of employment for a new employee and successful progress in educational effort a prerequisite to promotion. The Graduate School of Banking was organized in 1935 to extend the work of the American Institute of Banking. Its student body consists of bank officers desirous of taking advantage of educational opportunities of an advanced character in the fields of their professional interest. In addition to these measures for improving the technical qualifications of the younger banking personnel, the state and national banker's associations hold throughout the country many regional bank-management conferences to enable senior bank executives to meet and interchange information regarding successful methods and desirable improvements in practical bank operations.

41

Trade Associations — Their Growth and Activities

Development of Trade Associations

Trade associations are an important factor in our economic system. Their development in the United States, their character, their activities, and some of the major factors relating to their operations briefly are treated here historically and descriptively. Much additional information is available in the numerous publications to which references are made.[1]

"A trade association may be defined as an organization for mutual benefit, composed of independent business concerns engaged in the same kind of industry or trade, and designed primarily to affect the conduct of that industry or trade."[2]

American trade associations are not to be confused with the European cartels or the medieval guilds. They are distinctive organizations of business-men, operating under a competitive economic system, a republican form of government, and a democratic society.

Government officials, the courts, educators, scientists, and business men themselves today recognize the economic value of trade associations to business, to society, and to the Government. They are voluntary [illegible] and flexible in operation; they do the job needed when needed, [illegible] programs vary under different economic conditions and under different circumstances, according to the requirements of our complex [illegible].

Early trade associations in the United States. In *The Life of George Washington*, by W. E. Woodward, reference is made to the [illegible] in 1762, of the spermaceti candlers. The [illegible] Company of Philadelphia, organized in 18[illegible] [illegible], clearly indicates that [illegible] [illegible] in some of the early trade [illegible]. The constitution of this early organization [illegible] providing for improving the [illegible]

[illegible]

the industry and assisting those in need. One clause read as follows: "To improve ourselves in the science of civil architecture and to stretch out the hand of charity to such of our members, their widows and children who, by the unforeseen dispensations of Providence, may stand in need of assistance."

A united front in presenting the views of industry to legislative and administrative bodies was one of the first benefits realized from the collective action of trade groups. Writing-paper manufacturers of Boston met in May, 1819, to draw up a petition to Congress for greater protection from foreign competition. A committee was appointed to invite the coöperation of paper manufacturers of other localities in presenting this petition to the Sixteenth Congress.[3] The Writing Paper Manufacturers' Association, which was organized on February 13, 1861, had as its object "to meet and deliberate on all subjects pertaining to its business." This organization is still an active, aggressive agency, carrying on definite activities to promote the standards of the writing-paper industry and to improve its service to the public.

The history of the National Association of Cotton Manufacturers, which was organized originally as the Hampden County (Massachusetts) Mills Agents' Association, in 1854, is typical of the growth of many national associations. In this instance, as in most others, the organization of a local trade association preceded that of a national association in the industry.

The Silk Association of America, Incorporated (now the National Federation of Textiles, Incorporated), organized in 1872, the American Paper and Pulp Association, organized in 1878, the American Dental Trade Association, organized in 1882, and the National Paint, Oil, and Varnish Association, Incorporated (now the National Paint, Varnish, and Lacquer Association, Incorporated), organized in 1890, are just a few of the many organizations formed during this early period that have continued to carry on, in behalf of their respective industries, a program which has also been in the public interest.

The formative period (1890 to 1910). The period from 1890 to the advent of the open-price arrangement, in 1911, has been referred to as the "second stage" in the development of trade associations. Frequently, it also has been termed the "formative stage" of their development. Businessmen were desirous of adjusting their activities—that is, coördinating their promotion and sales policies—more intelligently and more accurately on the basis of the best technical practice and actual market conditions.

The First World War decade. Between 1910 and 1920, particularly, is notable in the history of trade associations because of outstanding developments in four phases of association work which are more fully described under activities. They relate to statistics, codes of ethics, standardization, and war-service activities. A number of associations

[3] See *Development of Trade Associations*, Trade Association Division, Chamber of Commerce of the United States (1938).

now active in preparedness matters had their origin in war-service committees created during the First World War; in fact, about 56 per cent of the national and regional associations active today were organized after the War.

The twenties. The decade from 1920 to 1930 was marked by several important legal entanglements, an extension of activities, and the widespread recognition of trade associations as an important factor in our economic life.

The Chamber of Commerce of the United States, in 1923, conducted a referendum on trade-association activities. Government agencies, particularly the Department of Commerce and the Federal Trade Commission, extended their work with organizations as a means of increasing the efficiency of management and eliminating unfair methods of competition.

The thirties. During the decade from 1930 to 1940, trade associations were confronted with three forces that challenged their ability and their versatility: the depression, the NIRA, and the attack upon business and business organizations Truly representative, properly organized, and ably directed associations were successful in counteracting the forces which threatened to weaken, if not to destroy, coöperative efforts by businessmen, with the result that these forces have ultimately strengthened trade associations.

Most trade associations operated with fewer members and less revenue during the depression A few organizations had created surplus funds which served useful purposes during the early years of the depression. Generally, however, trade-association activities were reduced in scope or temporarily suspended, although the organizations remained intact

National Industrial Recovery Act For over a quarter of a century, trade associations had been aggressive opponents of unfair competition. Thus, upon the enactment of the National Industrial Recovery Act and the Agricultural Adjustment Act, these business organizations became the energizing nucleus for the submission and administration of codes. Businessmen and business organizations devoted time and effort unsparingly to aid the Government

The greatest stimulus to the trade-association movement since the First World War was given by the passage in June, 1933, of the National Industrial Recovery Act, according to the Division of Review of the National Recovery Administration.[4]

The NIRA, in its early months, relied upon trade associations, not only to draft and present codes, but also to administer them. However, this policy was later modified in favor of independent agencies elected by the industry at large. There were 886 approved codes, including supplementary and divisional codes. Of these, 219 codes, or about 25 per cent of the total, provided that the entire code authority should be from, or elected by, trade associations; 157 codes provided that the president and/or the secretary of the code authority should be such officers from

---

[4] *Work Materials* Number 46 (March, 1936).

the trade association; 169 codes required that the election of the code authority be supervised by trade associations; and 331 codes provided that a majority of the code authority should be from, or elected by, trade associations.

Trade-association executives look upon the code period with mixed emotions. Viewing it objectively, it possessed both beneficial and harmful forces. In the initial stages, unusual benefits were anticipated. Many men and organizations worked together more seriously and more extensively than ever before. Some of the harmful forces were: (1) trade associations were threatened to be supplanted or overshadowed by code authorities—a new type of Government regulatory agency; (2) coöperative activities were limited to those approved by the Government as essential in carrying out the purposes of NIRA; and (3) the principle of voluntary membership was supplanted in many cases by that of compulsion.

Postcode reorientation. Fortunately, a number of trade associations had continued their regular programs during the code period. Other organizations reinstituted association activities before the codes were annulled by the Supreme Court opinion of May, 1935. The postcode period was marked by appeals for voluntary action, as contrasted with threats of compulsion and the enunciation of "thou shalt" or "thou shalt not" included in innumerable code "edicts" or regulations.

Efforts to increase the demand for products were evidenced in the many promotional programs of this period. Employee training again became an important activity of many organizations.

Preparedness activities. New tasks confronted trade associations in the forties. The national-defense preparedness program launched by the Government in 1940 presented new opportunities for public service.

The recent actions of trade associations in those industries directly affected by the movements toward military preparedness constitute another evidence of their flexibility, of their willingness, and of their ability to aid the Government and business. A number of organizations had for years been working with the Army and Navy upon production problems.

Such contacts have been extended; in fact, more groups are working on more problems than at any time since the First World War. The National Defense Advisory Commission to the Council of National Defense has appointed to its staff "group" consultants and special committees to deal with special problems affecting particular industries. For instance, in the petroleum industry, a technical committee is working on gasoline for airplanes and another on storage problems. A consultant and advisory committee on trade-association contacts is working with the Bureau of Research and Statistics of the Commission.

The staff, consultants, and committees, however, are appointed by and are responsible to the Government, and not to any special business, labor, consumer, or other particular group.

Much of the new work represents an extension or readjustment of established activities, with special reference to the defense situation.

It is still too early to envision all of the tasks which may engage the attention of trade associations. Publications of the Chamber of Commerce of the United States have cited specific activities of organizations. It is sufficient to indicate here how associations have made available their knowledge, their judgment, and their experience in such tasks as:

(1) Selecting business leaders as consultants.
(2) Disseminating information.
(3) Ascertaining industry opinion and judgment, particularly with respect to sound managerial policies.
(4) Identifying sources of information and dealing with special problems with respect to materials, supplies, and equipment.
(5) Surveying facilities and services of industries.
(6) Revising or preparing specifications and designs.
(7) Establishing product standards.
(8) Eliminating "bottlenecks."
(9) Appraising and solving new employment problems, such as employee training, labor shortages, and so forth.
(10) Balancing civilian and military requirements as a means of minimizing fluctuations or changes.
(11) Watching and endeavoring to counteract forces that might affect prices unduly.
(12) Coöperating with the Government in counteracting any forces that would retard the program or adversely and unwarrantedly affect the public interest.

In some fields, the number of firms which might furnish materials was extended. Contracts were negotiated and work initiated before all the factors, such as allowances for amortization, were known.

Character, Scope, and Structure of Trade Associations

Trade associations have developed as a part of our American economic system. Organized on democratic principles, they promote democracy; operated to increase the efficiency of management, they further our competitive capitalistic system.

The complexity of our economic and industrial life is portrayed in the multiplicity of organizations representing various phases of American industry. Organizations exist which frequently are termed "trade associations," yet they do not comply with the generally accepted definition of a trade association

Trade associations representing a field of business should be distinguished from the general business associations—commercial organizations, such as chambers of commerce, boards of trade, and merchants' exchanges; professional, technical, or strictly functional organizations.

Definitions and descriptions. The Special Committee of the Chamber of Commerce of the United States, in its report on trade associations in 1923, defined trade associations as follows:

> A trade association may be defined as an association formed in a field of industry or commerce with a membership so representative that all problems pertaining to this field can be adequately presented for common consideration and solution and with the purpose of developing this field so as to have the enterprises in it conducted with the greatest economy and efficiency. Other organizations with a membership which is less representative and other organizations with their attention limited to a portion of the problems in a field may be highly meritorious but they would not be properly described as trade associations and should use titles and other descriptions which will accurately indicate their character.

Functional organizations. Organizations of a technical or specialized nature have been developed which are somewhat similar to trade associations. There are a number of functional organizations, the membership of which consists of business firms interested in a particular functional problem. Such members may represent very diversified industries. The American Standards Association, the Textile Color Card Association of the United States, Incorporated, and The National Board of Fire Underwriters are illustrations of the functional type of organization.

Service organizations. Special service organizations also have been created within a single industry. Such groups are organized frequently on the same basis as a trade association but are authorized usually to carry on only one or a very limited number of activities. From the standpoint of organization structure, they are not different from trade associations, which carry on more diversified activities. Some associations may be interested primarily either in trade promotion, such as National Ice Advertising, Incorporated, or in the establishment of certain standards, such as the Tire and Rim Association, Incorporated. Other associations deal only with credit matters, while a few are interested only in foreign trade. There are 43 organizations operating under the Webb-Pomerene Act in connection with foreign-trade work for their respective industries.

Technical groups within single industry. The technical and professional individuals within certain industries have formed organizations to consider the special technical or professional matters confronting those engaged in the same industry. Illustrations of such organizations are the American Association of Textile Chemists and Colorists, the Society of Automotive Engineers, Incorporated, and the American Pulp and Paper Mill Superintendents' Association. These same individuals, of course, may also belong to the general national organization representative of their entire profession, such as the American Chemical Society.

In some fields, no separate independent agencies are organized; instead, special groups—such as accountants, production managers, technicians, and sales managers—work through divisions of the trade association.

Structure and operation. *Voluntary membership.* Most trade associations are representative of "a business," in contrast with most professional organizations, which are representative of the "individual." The constitutions and bylaws of trade associations, therefore, provide for the

membership of firms, corporations, or individuals, as well as organization memberships in so-called "federated" associations.

In some cases, membership is divided into two classes—active and associate. The associate member is usually denied the right to vote and to hold office. Active membership is usually limited to persons, firms, or corporations engaged directly in the particular branch of a trade which the association aims to represent. The associate membership usually consists of the sellers or the buyers of the product manufactured or handled by the active members.

A few associations include as many as 8 or 10 types of membership. Such organizations, however, usually provide for an affiliated organization membership, a corporation membership, and several types of individual membership representing technical groups within the industry. The so-called "federated" associations have organizations as members. In some instances, the control of the national organization is in the hands of such affiliated organizations. In contrast with the federated organizations, there exist direct-membership organizations, the individual firms or corporations of which hold direct membership in and pay dues directly to the national association.

Control. The control of these organizations is vested in the membership. In over 85 per cent of the cases, each member is entitled to one vote only, irrespective of the amount of dues paid. Bylaws usually provide that the active management shall be vested in a board of directors, which is elected by the membership and is truly representative of the different geographical regions or commodity sections, as well as the large and small firms. Representative committees are usually investigatory and advisory in character.

In some associations, the amount of committee work required is negligible, while in others, a very large amount of work is carried on through separate committees aided by a competent staff. Their recommendations are made to the board of directors, which, if the subject is of widespread interest and special importance, may refer the matter to the entire membership at an annual or special meeting. Through such procedures, the association acts as the "town meeting" of the industry.

Legal forms. In the earlier periods, comparatively few of the associations were incorporated. Today, slightly over 50 per cent of the national and regional associations are incorporated. As associations assumed legal responsibilities, entered into contracts—such as those for long-term advertising programs—desired to hold real estate, and so forth, the value of incorporation was recognized.

In a few cases, separate corporations have been formed to carry on specific activities, such as trade promotion. The experienced association executive does not look with favor upon the development of separate and independent organizations created for the purpose of carrying on specific activities, except under special circumstances.

Divisions. A number of associations have organized divisions, or branches, on two bases: first, territorially; and second, by type of business or group represented. Such plans of organization avoid the weak-

nesses of federated types of organization and, at the same time, permit consideration of problems by specific trade or regional groups. The National Electrical Manufacturers' Association embodies approximately 80 divisions, each representative of some line or product manufactured.

The National Fertilizer Association has established 12 districts representing geographical areas. Each division is represented on the board of directors. This is a common type of organization structure for a number of national associations.

In a few instances, associations have provided for both geographical and commodity divisions, with a commodity division within each geographical division, which in turn considers problems similar to those before the national commodity division.

Some associations have established branch offices in different sections of the country; others work in close coöperation with regional associations that may not be directly connected with the national association.

Staff. The staff of a small association may consist of only a chief executive and a stenographer. On the other hand, a few associations employ a staff of over 100 employees. Associations employ specialists in many lines, such as accountants, statisticians, engineers, scientists, educators, economists, writers, and lawyers.

Financing. Associations are financed by business on a voluntary and equitable basis. As indicated, trade associations are diversified in character. The detailed plans whereby revenues are secured vary considerably, but certain common principles prevail. The Trade Association Division of the Chamber of Commerce of the United States issued, in 1937, a report entitled *Financing a Trade Association.*

The basis of income from dues and the percentage of associations using each method, as indicated by recent surveys, is as follows:

Volume of business	38.8%
Flat rate	26.7
Unit of product	16.4
Number of employees	4.3
Capital investment	2.1
Agency rating	1.8
Payroll	1.4
Other	8.2

It should be noted that all of the methods, except uniform or flat rate, endeavor to distribute the cost of the association on the basis of the size of business. Thus, approximately 73 per cent of the associations use some method of distributing the cost on the basis of the amount or size of the business of its members.

Budgets vary widely from a few hundred dollars to several hundred thousand dollars annually. The average annual budget of 1,166 national and regional trade associations, reporting to the Department of Commerce in connection with its survey[5] for the Temporary National Eco-

[5] Pearce, C. A., *Trade Association Survey,* Department of Commerce, TNEC Monograph No. 18.

nomic Committee, was $48,000 for the year 1937–1938 On the other hand, one half of the group receive less than $15,000, and 20 per cent receive $2,500 or less. Only 14, or about 1 per cent of the total number surveyed, receive $500,000 or over.

Reports from 1,166 national and interstate trade associations indicated a total membership of approximately 550,000 and annual expenditures of about $70,000,000. Of the 795 national and regional associations in the mining, manufacturing, and construction industries, 309 reported an annual income of $20,000 or more

An annual membership and income survey made by the United States Chamber of Commerce indicates that associations received more revenue and had a larger membership in 1939 than in any preceding year.

Among practices and trends reported in association financing, the following deserve mention:

(1) A specific program of activities, incorporating an indication of their scope and the procedure to be adopted, should constitute the basis of a financial budget.

(2) A well-developed and detailed budget of receipts and expenditures, with adequate accounting control, is essential to the sound financing of an association.

(3) An increasing number of associations use functional, departmental, or project classifications, as well as classifications on the basis of accounts —such as salaries, traveling, and so forth—in preparing budget proposals and in submitting financial reports.

(4) Numerous associations emphasize the necessity for maintaining a reserve or surplus sufficient to carry on the association program for a period of from 6 months to 1 year.

(5) In order that the association may be equitably financed, an increasing number of associations use, as a basis for dues, the size of a business, as evidenced in volume of sales, productive equipment, or number of employees.

(6) The major portion of the income of an association, in most cases, should be based on dues. Although it may be expedient or necessary to make separate charges for the operation of credit bureaus, collection, traffic, and similar services, it is neither practical nor sound organization policy to make every association activity independently self-supporting

(7) Raising the major portion of the budget by indirect means—such as publishing magazines, holding expositions, and establishing featured service arrangements on a fee basis—may tend to subordinate general activities and impair the carrying out of a rounded association program.

Number of associations. Today, practically every industry or trade is organized into a local, regional, or national association, and a few of the associations are international in character. It has been estimated that there exist some 1,500 national, international, and interstate organizations, about the same number of state organizations, and about 4,500 local trade associations

It is estimated that 65 per cent of the 1,500 national and interstate

trade associations represent manufacturing, mining, and construction; 11 per cent, wholesaling, and 6 per cent, retailing.

The TNEC survey[6] reports that 1,313 national and regional associations are representative of the following business fields:

Fishing industry	7
Mining, manufacturing, and construction	858
Wholesale trades	147
Retail trades	85
Finance and real estate	25
Insurance	67
Transportation, communication, and other public utilities	69
Personal business, recreational, and service trades	55

On the other hand, of the total of 7,500 trade associations, it is estimated that they represent business groups about as follows:

Manufacturing	2,000
Wholesaling	600
Retailing	2,900
Business service	2,000

The number of associations within particular industries or lines of business may run into the hundreds The National Association of Retail Grocers is a federated type of organization representing approximately 43,000 individual retailers who hold membership in over 600 local organizations and about 36 state retail-grocer associations. Each individual member of the National Association must first join his local association, which in turn affiliates with the state association, which is represented in the National Association. There are over 300 national organizations representative of different phases of the construction industry.

Trade-Association Activities

Activities of trade associations are numerous in scope and varied in character. A classification of association activities, as developed in 1938 by the Trade Association Division of the Chamber of Commerce of the United States, in coöperation with trade-association executives, shows 30 activities that may be carried on by trade associations. This classification[7] also includes about 200 subheadings showing a logical subdivision of the 30 activities of a general character.

The Department of Commerce, in its survey of trade associations for the Temporary National Economic Committee, used rather broad general subject headings, as follows: (1) Production and Purchasing; (2) Marketing; (3) Trade Promotion; (4) Trade Practices; (5) Trade Information; (6) Employer-Employee Relations; (7) Government Relations; and (8) Miscellaneous. Each of these headings was subdivided; for instance, the classification of Production and Purchasing covered: (*a*) Standardization and simplification; (*b*) Establishment of quality

[6] *Ibid.*

[7] A copy may be secured from the Trade Association Division, Chamber of Commerce of the United States

standards; (*c*) Registration of patents, trade-marks, designs, and styles; (*d*) Patent cross-licensing or pooling; (*e*) Used-machinery exchange; (*f*) Operations of research laboratory; (*g*) Other forms of technical research; (*h*) Coöperative buying; and (*i*) Technical advisory services.

Activities carried on by the largest number of associations are: government relations, trade promotion, standardization and simplification, conventions, trade practices, trade statistics, employer-employee relations, miscellaneous services, technical research, and public relations Government relations is an activity carried on by over 80 per cent of the associations and outranks all others in terms of frequency of occurrence.

Functions of associations. The function of a trade association may be to determine policies, to promote specific activities, and to render specific services. The organization may consider economic problems, ascertain the opinion of the industry, and develop a definite policy relating thereto. A program may be adopted relative to legislation or public relations involving the development of trade customs or codes of business practice.

After a policy has been developed or an educational program outlined, the association may then become a motivating agency, carrying the policy to the members of the industry and, in general, conducting those activities which are aimed to assist in the execution of particular policies

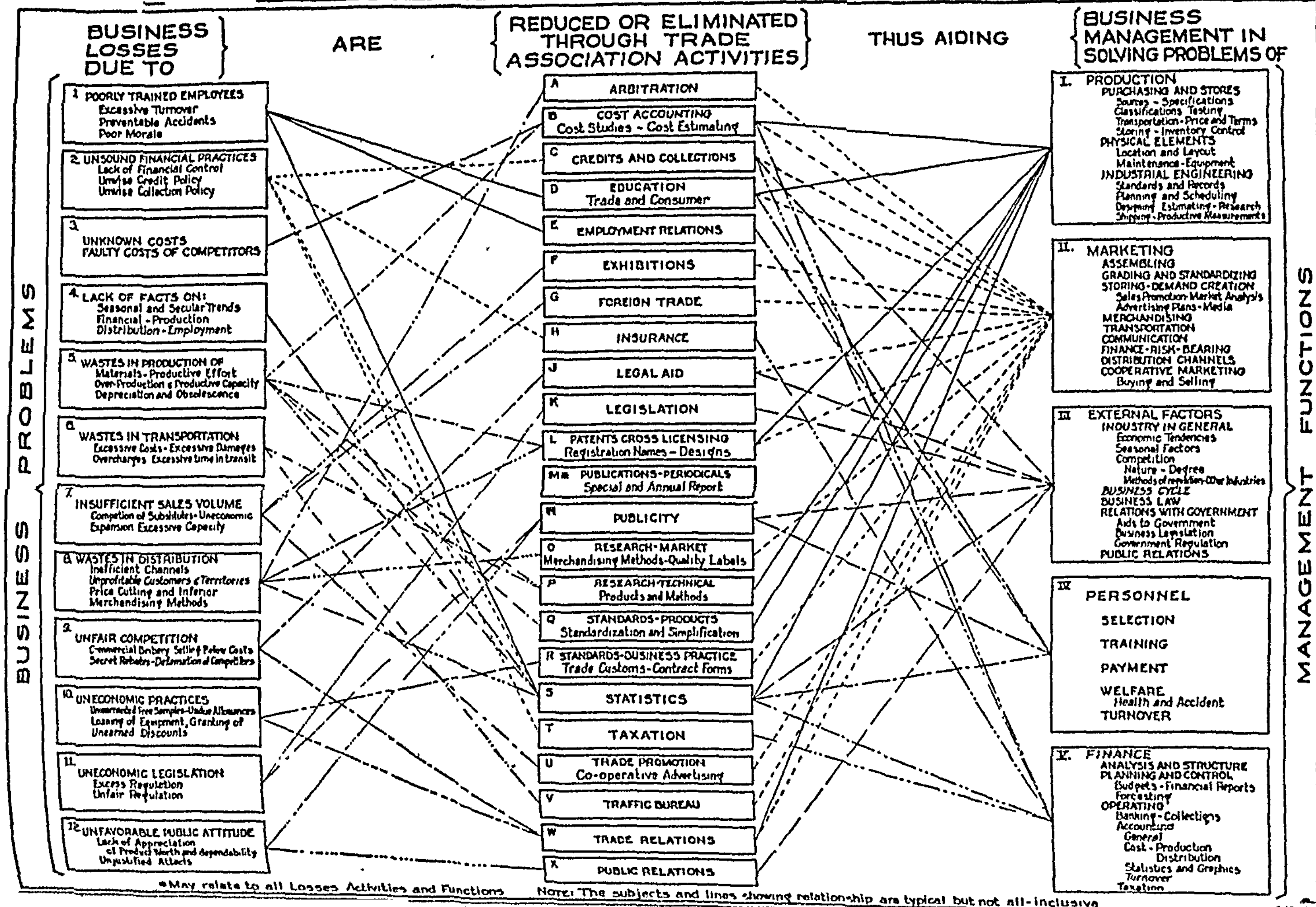
Apart from the work of developing or formulating policies or promoting activities, an association may render certain specific services. While many of the activities are of a service character, the experience of trade associations would seem to indicate that a group which is only a service organization does not fully represent the industry in the consideration of all of its problems.

Functions of business management. The functions of business management are frequently divided as follows: (1) production; (2) marketing; (3) personnel; (4) finance; and (5) administration. The trade association with a comprehensive program is in a position to aid management in solving many of the common problems arising within these five groups that are susceptible of group effort. Obviously, the association cannot be charged with the responsibility of business management itself. In other words, the trade association is not an agency to keep in business those who are inefficient, unprogressive, unskilled, or untrained; nor is it an agency that endeavors to keep in business those who desire to get more than they give or those who preach business ideals but practice unfair methods of competition. On the other hand, the trade association with a comprehensive program may aid in meeting practically every business problem, whether it be untrained employees, credit losses, unknown costs, surplus stocks, wages, production or distribution, uneconomic competitive practices, or lack of standards.

The chart on page 952 indicates how association activities are correlated to the functions of business management

Trade promotion. Competition is interindustry as well as intraindustry. Consumer demand for a class of products or service is a prerequisite

W T_ .E ASSOCIATIONS CONTRIBUTE TO THE PROFITABLE OPERATION OF BUSINESS



to the acceptance of a particular article or service in that field. Thus people must be made conscious of the desirability of building a home before they select the particular items that constitute the materials in a house; they must be automobile-conscious before they select a particular make of car. The development of consumer desire for a general class of products is appropriately a coöperative job, which may be carried on more economically through a trade association than by the individual and uncorrelated efforts of each unit in the industry. Such are some of the principles and conditions which have motivated businessmen to engage coöperatively in extensive trade-promotion programs.

Of 1,244 national and regional trade associations reporting, 876, or 70 per cent, reported that they were engaged in some form of trade promotion during the period 1938–1939 Of the total number, 619, or approximately 50 per cent, reported a major emphasis on trade promotion.

Trade-promotion programs may involve a variety of separate activities. The varying characteristics of different industries make it impossible to catalogue in advance any complete list of activities which should be incorporated in a comprehensive trade-promotion program.

Among some of the activities which have been carried on as phases of a well-rounded promotional program are: (1) technical and scientific research; (2) market research; (3) advertising and publicity; (4) field service; (5) employee training.

Technical and scientific research. New uses for products and new and better products may be developed through technical or scientific research. Increased knowledge concerning the character of the product, its serviceability and performance, may aid in extending its work.

Some trade associations maintain their own laboratories. They coöperate with educational and Governmental agencies in conducting special research projects. In some cases, a technical-research committee of the association outlines a series of research projects, different phases of which are carried on in the research laboratories of the individual companies. The nature of the investigations covers a wide range, involving consideration of microscopical, bacteriological, chemical, thermological, metallurgical, toxicological, and other research The commodities range from animal and vegetable products to oil, machinery, and chemicals.

Nearly 44 per cent (542 out of 1,244 reporting) of the national and regional associations were engaged in some form of technical research or advisory services during the period 1938–1939.

Market research. The analysis of existing potential markets and a study of the channels of distribution enable the industry, not only to do a better distributive job, but also to expand its promotional work in those areas or among those classes of customers in which there exists the greatest possibility of market promotion.

Market research may also involve an analysis of demand with reference to styles, sizes, designs, colors, or grades, as well as the establishment of dimensional and qualitative standards supplemented in some cases by certification, labeling, or grading as a means of aiding the

purchaser. It may also relate to an analysis of unprofitable customers, items, territories, and merchandising practices.

Advertising and publicity. "Say It With Flowers," "Save the Surface and You Save All," and "Trade-Marked—Grade-Marked Lumber" are slogans known by thousands today because of coöperative promotional efforts. Associations use practically all advertising and publicity media, inasmuch as each association program must be custom-built. There is considerable diversification in the advertising and publicity program of different associations. In some instances, national advertising matter is utilized, whereas in other instances a national program may involve very largely local advertising and promotional work.

Field service. Associations have employed trained engineers, dieticians, and other specialists to acquaint users with the values and technical uses of their products. Field men employed by construction and material industries may contact architects, engineers, and contractors; whereas dieticians and home economists may contact the teachers of home economics and various women's organizations. In other cases, general as well as technical field-promotional work is considered part of the trade-promotion program.

Standardization and simplification. The field of standardization is one which is engaging the attention of more and more trade associations. But it is not a new activity. One organization, the Manufacturers' Standardization Society of the Valve and Fittings Industry, was formed more than 30 years ago with this purpose expressly in view. This exemplifies the interest which trade associations have taken in dimensional standards. They have coöperated with the Bureau of Standards since its inception, in 1901. The bureau has the help of associations in deciding on commercial standards common to more than one industry. A number of associations maintain fellowships there to further their work in this line. They have long coöperated in establishing simplified practice recommendations, determining the one fifth in sizes that constitutes four fifths of the sales.

In the association field there are two groups devoting their efforts exclusively to the broad field of standardization, the American Society for Testing Materials and the American Standards Association. The former has for its purpose "the promotion of knowledge of the materials of engineering, and the standardization and the methods of testing." The latter, originally called the "American Engineering Standards Committee," acts as a clearing house for standardization work being done in the United States and elsewhere, promotes standardization, and prevents duplication of effort.

Besides dimensional standards, trade associations have interested themselves in quality standards, the characteristics of a product that fit it for a given use The associations affiliated with the National Lumber Manufacturers Association have established standards for lumber based on freedom from defects; members mark each piece with the correct grade or send a certification along with carload lots. The American Gas Association has set up specifications for gas appliances which manufacturers

are required to meet before the product can carry the Association seal of approval; maintenance of standards is assured by examinations in the A.G.A. Testing Laboratories.

Standards for consumer goods are receiving increasingly more attention from trade associations. In such matters as the truth-in-labeling legislation, it is usually the trade association that counsels with the Government and other agencies in formulating sound and practical policies. The American Standards Association has an Advisory Committee on Ultimate Consumer Goods, representative of consumer and business groups, to study the many problems facing the establishment of satisfactory standards.

Through coöperation with educational institutions and private laboratories, as well as through work in their own organizations, trade associations have done much to establish standards that guarantee size or performance and reduce dissatisfaction and return of goods. They have fostered simplification of sizes, which decreases the number of inventory items and facilitates the production of stock during slow periods, thus reducing the cost of production and distribution.

Statistics. The compiling, analyzing, and disseminating of statistics are activities that may relate to all of the problems of business management; for instance, statistics may relate to production, sales, employment, and costs. Trade-association production and sales information include statistics on such subjects as new orders, unfilled orders, cancelations, sales, shipments, production, inventories, and capacity. Such statistics:

(1) Show the relative position of each industry to all industry.
(2) Enable each concern to ascertain its relative position within the industry.
(3) Aid the individual concern in the industry in stabilizing production and employment.
(4) Aid the industry in stabilizing earnings.
(5) Identify centers of demand and purchasing power.

The above-mentioned types of statistics are discussed in detail in a publication of the Trade Association Division of the Chamber of Commerce of the United States entitled *Use of Trade Association Statistics in Manufacturing* (1937). A somewhat similar pamphlet, published under the same auspices, *Use of Trade Association Statistics in Retailing* (1939), discusses how retail-trade-association statistics can be used as guides to profitable retailing.

Statistics form the basis for important phases of other trade-association work, such as public relations and presentation of economic briefs in connection with matters arising before legislative or administrative agencies of the Government. Statistics represent one of the oldest and most widely conducted activities of trade associations. At the organization meeting of the National Association of Wool Manufacturers, in 1864, reference was made to the need for collecting information concerning the industry.

The name "open-price association" was originated by Arthur Jerome Eddy, a Chicago lawyer, who, in 1912, published *The New Competition*.

At the request of the Joint Commission of Agricultural Inquiry of Congress, under date of July 16, 1921, the Federal Trade Commission undertook a special investigation concerning the activities of trade associations. The report[8] indicated that 150 out of 1,515 associations replying were distributing or exchanging price information.

The Brookings Institution, in 1936, made a survey of some of the economic issues involved in open-price work and set forth the general subjects of public policy involved in the organization of open-price plans.[9]

The Trade Association Survey for the Temporary National Economic Committee also discusses this subject. The report indicates that the functions of trade associations, with reference to association statistics, might include, in the first place, the establishment of standards for the dissemination of trade-association statistics to interested parties in the trade other than participants in the reporting plan—whether competitors, customers, or suppliers. A rather extensive discussion is included with respect to statistical work of trade associations and some of the major problems arising in connection therewith.

Reference to some of the legal cases involving trade associations, discussed later in this chapter, indicates some of the problems involved with respect to this type of activity. In general, however, it may be said that, through the years, trade associations have extended their statistical activities in character and scope. This work has been increasingly beneficial to management in solving the internal problems, as well as in dealing with Governmental and public problems.

Accounting. The elimination of waste, the curtailment of inefficiencies, and the establishment of fair competitive practices represent the objectives of trade associations in promoting sound accounting and cost-finding principles.

The uniform cost movement among members of trade associations dates back almost to the beginning of the present century; for instance, in 1906, the printers set up a committee to study the question of cost finding. In 1917, the Chamber of Commerce of the United States commended the Federal Trade Commission for its efforts to bring about universal recognition of uniform systems of accounting. The chamber has published material[10] to assist those interested in this phase of work.

Wholesale, retail, and service organizations have conducted extensive cost studies. The National Retail Dry Goods Association conducts an annual cost study in coöperation with the Harvard Bureau of Business Research. A number of organizations coöperated with the Department of Commerce in cost studies in the jewelry, grocery, and drug fields.

---

[8] *Open-Price Trade Associations*, United States Senate Document No. 226, 70th Congress, 2nd Session (1929).

[9] *The Economics of Open Price Systems*, Institute of Economics of the Brookings Institution (1936).

[10] *Uniform Accounting Activities of Trade Associations*, Chamber of Commerce of the United States.

It is estimated that approximately 50 per cent of all national associations are engaged in some phase of accounting or cost-finding work.

Employer-employee relations. *Employee training.* The maintenance and development of the "arts" of the industry constituted a purpose of some of the earliest organizations. From the promotion of craftsmanship to the training of the engineering and other professional groups represents the broad range of employee training fostered by trade groups. In fact, such organizations maintain their own schools; they coöperate with educational institutions; they prepare textbooks; and they aid the individual members of the industry in conducting "in-plant" training. The American Institute of Baking, the American Institute of Laundering, and the National Association of Dyers and Cleaners of the United States and Canada own and operate their own schools. The American Bankers Association has enrolled, through its affiliated and coöperating organizations, over 40,000 students.

Considerable material[11] has been published on this and related phases of association work which undoubtedly will become increasingly important as the defense program develops.

Safety and welfare. Economic and social losses are reduced through safety and welfare activities of associations. Not only promoted are campaigns within the industry, but such organizations also coöperate with Governmental agencies in efforts to reduce accidents and maintain healthy employment conditions. Associations in the coal, cement, and meat-packing industries have for years conducted safety campaigns.

Collective bargaining. National associations furnish information concerning collective bargaining. They survey employment conditions throughout the country. But almost without exception, such national organizations are not agencies for collective-bargaining purposes.

Locally, the trade group may assume the functions of collective bargaining. On the other hand, many activities may be handled by a local employers' organization set up for such purposes.

Surveys informational services. During the past decade, new phases of the employer-employee problem have been undertaken by trade associations. Studies of employment conditions covering wage rates, hours of employment, and so forth have been made, not only as a direct aid to management, but also in connection with numerous Governmental matters involved in administration of the NIRA, the Walsh-Healey Act, and the Fair Labor Standards Act.

During the period 1938–1939, service in the general field of employee relations ranked fourth among the activities of national and regional associations and seventh among the major activities of these associations; in fact, 61 per cent render one or more types of employer-employee service.

Trade relations. The promotion of higher standards of competitive conduct has been a continuing activity of trade associations The by-

[11] See *Employee Training Activities of Trade Associations* and *Employer-Employee Relation Activities of Trade Associations*, Chamber of Commerce of the United States.

laws of associations organized prior to 1900 included such objectives. With the years, emphasis has been placed upon different methods to attain such purposes. During the early part of the decade 1910 to 1920, hundreds of trade associations and professional and technical organizations adopted codes of business ethics. This new philosophy was reflected in the truth-in-advertising movement, in the passage of the Federal Trade Commission Act, and in the organization of service clubs, many of which also included as one of their objectives the furtherance of equitable standards of business conduct. A code of business standards was adopted and extensively distributed by the Chamber of Commerce of the United States in 1924.

The Federal Trade Commission, in 1917, began to hold trade-practice submittals, or, as they are now called, trade-practice conferences. This movement reached its peak in the latter part of the twenties. In fact, during the period 1928 to 1930, over 100 industries held trade-practice conferences under the auspices of the Federal Trade Commission.

The next great movement, from 1933 to 1935, was in connection with the submission of NIRA codes. Since then, some trade associations have reaffirmed the code of ethics adopted over a quarter of a century ago. In the 4 years following the demise of the NIRA, trade-practice-conference rules were promulgated for 39 industries. In some fields, emphasis has been placed upon new legislation, such as the state fair-trade and unfair-practices acts and the more recent Federal legislation, the Robinson-Patman Act, prohibiting price discrimination as a means of establishing better standards of business conduct.

In many general as well as specific ways, trade associations have endeavored to eliminate unfair and wasteful practices and to secure the adoption of business standards that are fair to competitors, to buyers, and to sellers.

Government relations. Relations with the Government represents one of the most common activities of trade associations. It is estimated that over 80 per cent of the associations engage in activities in which government—Federal, state, or local—is involved.

The activities cover a wide range. They pertain to matters of legislation involving all business and specific fields of business. Taxation and tariff, as well as special model laws, receive the attention of trade groups. Trade associations are dealing more and more with administrative and quasijudicial agencies of government. Briefs are submitted and witnesses are secured to present the point of view of business with respect to proposed Government regulations by the increasing number of regulatory bodies.

More and more trade associations are requested to furnish information which may be helpful to Government agencies. Associations also coöperate in connection with research projects, educational programs, and a wide variety of matters not of a regulatory character.

Public relations. Public relations, as a trade-association activity, is selling the industry, the business, or the institution, but not the product. It takes many forms. Publicity concerning the activities of the associa-

tion or industry is a common form of public relations. A research program that has developed a new use or a by-product interests the public. A fellowship awarded for study in a selected field generally is of interest to the public and to industry. The announcement of a safety contest or seeing a film on safety at a social meeting makes the layman appreciate the concern of the companies in the welfare of the employees. Reports of savings through standardization and simplification programs find a receptive audience. The association code of ethics arouses greater respect for the members. Facts about the industry in advertisements and leaflets, and the ready availability of more information, are among the best means associations use for gaining popular support and good will.

Proper public relations do not merely explain and expound business conduct in order to produce a favorable reaction by the public but also guide the members in the proper performance of their activities; that is, a good public-relations program anticipates the ammunition that will be used against the industry. Are employee relations unsatisfactory? If so, improve them.—Are farmers led to believe that industry gouges them? Give them the facts.

The problem of public relations is not limited simply to the general public but rather to all affected by the industry, directly or indirectly—employees, stockholders, buyers, customers, and transporters, or those serving these groups.

Associations representing the railroads, the automobile manufacturers, the bankers, the insurance companies, and many other fields of business have developed rather extensive public-relations programs. *Steel Facts, Automobile Facts,* and *Bus Facts,* are illustrations of a few association publications issued as part of such efforts. Such material is made available to newspapers, to educators, to public officials, to community leaders, and to others active in molding public opinion. Plant "open-house" days are encouraged by trade associations as another practical and realistic way in which the public may see the actual operations of business and the conditions under which employees work.

The Chamber of Commerce of the United States supports programs of industry public relations by giving intimate glimpses of the manner in which industry meets and solves its problems. Through advertisements, it brings before the people factors in emphasizing industry's side of the picture on questions of the day.

Other activities. To this list of four "family relations"—namely, employer-employee relations, trade relations, Government relations, and public relations—others might be added, such as customer relations, dealer relations, and buyer relations.

As previously indicated, trade associations carry on many other activities. Conventions or meetings constitute an important phase of organization work, whether attended by the members of a small committee or by several thousand people. In either case, detailed preparations must be made if the meeting, conference, or convention is to be of real help to the industry.

Trade journals, business papers, and numerous books[12] include descriptions of the many varied activities.

Public Policy and Legal Aspects of Trade Associations

To eliminate certain abuses, enactment of types of statutory restriction was deemed necessary. In order that these prohibitions might be made coextensive with the large-scale enterprise and national markets that were being aggressively developed, Federal action was deemed indispensable. The Interstate Commerce Act, which related only to common carriers, was passed in 1887; and between 1887 and 1897, 20 states had enacted laws prohibiting restraint of trade and monopolistic combinations under severe penalties.

As it has well been said:

> Democracy, in industry as well as in government, is the American ideal. Our laws regulating the conduct of business have all been formulated to protect the individual trader, to encourage initiative, to preserve opportunity, and to maintain for the public the great political, social, and economic benefits which flow from a competitive system of industry. Two rules of competition of great economic importance have been written into our statute books. The one prohibits all unreasonable restraints of trade. The other, supplementing the first, makes unlawful the use of unfair methods of competition. These two prohibitions, while modified and amplified by other statutes, embody the spirit and purpose of the federal regulation of business.

The Sherman Antitrust Act. In 1890, Congress passed the Sherman Antitrust Act. The first two sections of this act read as follows:

> *Sec. 1.* Every contract, combination in the form of trust or otherwise, or conspiracy, in restraint of trade or commerce among the several States, or with foreign nations, is hereby declared to be illegal. Every person who shall make any such contract or engage in any such combination or conspiracy, shall be deemed guilty of a misdemeanor, and, on conviction thereof, shall be punished by fine, not exceeding five thousand dollars, or by imprisonment, not exceeding one year, or by both said punishments, in the discretion of the court.
>
> *Sec. 2.* Every person who shall monopolize, or attempt to monopolize, or combine or conspire with any other person or persons, to monopolize any part of the trade or commerce among the several States, or with foreign nations, shall be deemed guilty of a misdemeanor, and, on conviction thereof, shall be punished by fine not exceeding five thousand dollars, or by imprisonment not exceeding one year, or by both said punishments, in the discretion of the court.

Although the Sherman Act was originally designed to prevent the suppression of competition through a combination and consolidation, the restraining sections apply equally to trade associations. The statute does not deal specifically with trade associations as distinct from other forms of business organization. The language of the statute and the court decisions indicate, however, that the form of organization or the methods used to suppress competition are immaterial.

---

[12] See Bibliography on trade associations of the Trade Association Division, Chamber of Commerce of the United States.

"Rule of reason." As clearly indicated, the definition of the meaning of provisions of the Sherman Law was left to the court. In the earlier decisions under the Sherman Act, the Supreme Court was supposed to construe literally that *every* contract, combination, or conspiracy in restraint of trade was illegal. The Supreme Court, in its decision in the Standard Oil and the American Tobacco cases, in 1911, established what has been termed "the rule of reason." These decisions established the doctrine that only undue or unreasonable restraints of trade or monopolistic combinations were to be prohibited.

Clair Wilcox in, *Competition and Monopoly in American Industry* (a TNEC monograph), says that trade organization, in the twentieth century, took its initial impetus from the enunciation of the rule of reason and from *The New Competition,* by Arthur Jerome Eddy.

Antitrust legislation of 1914. What constitutes unfair competition as between competitors was placed before the courts in the early part of this century. About the year 1900, a manufacturer of washboards made an exclusive contract with the sole manufacturer of aluminum, so that he became the only manufacturer of aluminum-faced washboards. Soon he found another manufacturer placing a zinc washboard on the market and marking it "aluminum." He sought an injunction to prevent such a practice. The Circuit Court of Appeals denied the right to injunctive relief in an opinion worded as follows:

> Many articles are now being put on the market under the name of aluminum, because of the attractive qualities of that metal, which are not made of pure aluminum, yet they answer the purpose for which they are made and are useful. Can it be that the courts have the power to suppress such trade at the instance of others starting in the same business who use only pure aluminum? . . . We find no authority in the books, and are clear in the opinion that, if the doctrine is to be thus extended, and all persons compelled to deal solely in goods that are exactly what they are represented to be, the remedy must come from the Legislature and not from the courts.

This opinion, in effect, announced the rule that, irrespective of the fraud and deceit practiced by the defendant on the purchasing public and of the incidental injury suffered by an honest competitor, a court of equity was powerless to grant relief, as the act complained of was not directed against a specific competitor whose injury was merely incidental Observe, however, that the Court took pains to point out that "the remedy must come from the Legislature," thus placing upon the law-making power the responsibility for protecting the purchasing public and the honest competitor against injury through fraud and deceit.

In undertaking to discharge that responsibility, Congress, some 14 years later, enacted the statute creating the Federal Trade Commission, vesting it with power designed to suppress unfair methods of competition. Section 5 of the Federal Trade Commission Act reads in part as follows:

> That unfair methods of competition in commerce are hereby declared unlawful.
>
> "The Commission is hereby empowered and directed to prevent

persons, partnerships, or corporations, except banks and common carriers subject to the acts to regulate commerce, from using unfair methods of competition in commerce "

This act also created the Federal Trade Commission, the powers of which relate to investigation, publicity, and assistance to the Court, as well as to prevention of unfair methods of competition.

The Clayton Act. Congress, also in 1914, passed the Clayton Act, Section 2 of which reads as follows:

> That is shall be unlawful for any person engaged in commerce, in the course of such commerce, either directly or indirectly, to discriminate in price between different purchasers of commodities, which commodities are sold for use, consumption, or resale within the United States or any Territory thereof or the District of Columbia, or any insular possession, or other place under the jurisdiction of the United States, where the effect of such discrimination may be to substantially lessen competition or tend to create a monopoly in any line of commerce: *Provided*, That nothing herein contained shall prevent discrimination in price between purchasers of commodities on account of differences in the grade, quality, or quantity of the commodity sold. or that makes only due allowance for difference in the cost of selling or transportation, or discrimination in price in the same or different communities made in good faith to meet competition: *And provided further*, That nothing herein contained shall prevent persons engaged in selling goods, wares, or merchandise in commerce from selecting their own customers in bona fide transactions and not in restraint of trade.

As indicated, the purpose of this act was to prohibit those trade practices which Congress felt were not, singly and of themselves, covered by the existing antitrust acts, with the idea of arresting in their incipiency the creation of monopolies or unreasonable restraint of trade. In other words, the Clayton Act is directed at the potential evils. The act legalizes certain activities of farmer and labor organizations.

Additional legislation. The Shipping Act of 1916 and the Webb-Pomerene Act of 1918, as well as the Transportation Act of 1920 and the Merchant Marine Act of 1920. added certain exceptions to the Sherman Act. So did also the National Industrial Recovery Act of 1933 and the Miller-Tydings Act of 1937, which legalizes contracts in interstate commerce made under any of the 44 state fair-trade acts legalizing contracts between manufacturers or producers of identified goods and their distribution in a state. establishing the minimum resale prices or, in some cases. actual prices of such goods.

The antidiscrimination statutes enacted in 28 states also represent recent efforts to remedy allegedly unfair competitive practices through state legislation.

Court decisions. While it is impossible to refer in this general presentation to all of the court decisions directly affecting trade associations, a few citations are included to illustrate major developments.

Maple Flooring Manufacturers' case. The Maple Flooring Manufacturers'[13] case, decided in 1925. is particularly significant from the stand-

[13] *Maple Flooring Manufacturers' Association, et al. v. United States*, 268 U. S 563 (1925).

point of activities that may be carried on by trade associations. In this case, the decision reads in part as follows:

> We decide only that trade associations or combinations of persons or corporations which openly and fairly gather and disseminate information as to the cost of their products, the volume of production, the actual price which the product has brought in past transactions, stocks of merchandise on hand, approximate cost of transportation from the principal point of shipment to the points of consumption, as did these defendants and who, as they did, meet and discuss such information and statistics without however reaching or attempting to reach any agreement or any concerted action with respect to prices or production or restraining competition, do not thereby engage in unlawful restraint of commerce.

Sugar Institute case.[14] The Sugar Institute case, instituted by the Government in 1931 and decided by the Supreme Court on March 30, 1936, involved a large number of issues. Inasmuch as statistics constitute one of the most important activities of associations and one of the activities which frequently has been an issue in court cases, reference here is confined to this phase of the association program in this case. After the Linseed[15] decision, many eminent lawyers were of the opinion that open-price filing was permissible when limited to past or current transactions. Officials of the Department of Justice contend that the Sugar Institute opinion places the emphasis "on the unlawful agreement" and not on the form of statistical activity. It was the agreement to adhere to announced prices which was condemned in this case, in which Chief Justice Hughes says:

> Defendants' argument on this point is a forceful one, but we need not follow it through in detail. For the question, as we have seen, is not really with respect to the practice of making price announcements in advance of sales, but as to the defendants' requirement of adherence to such announcements without the deviations which open and fair competition might require or justify.

The case also dealt with the question of publication of statistics distributed by the association. The Court concluded that the purchasing and distributing trade has a legitimate interest in "vital data" relating to production and deliveries. However, "by collecting and circulating among themselves that information, defendants obtained an unfair advantage with respect to purchasers and effected an unreasonable restraint."[15] As the Court said:

> But it does not follow that the purchasing and distributing trade has such an interest in every detail of information which may be received by the Institute. Information may be received in relation to the affairs of refiners which may rightly be treated as having a confidential character and in which distributors and purchasers have no proper interest.

[14] *Sugar Institute, Inc., et al., v. United States*, 297 U S 553 (1936).
[15] *United States v. American Linseed Oil Co, et al.*, 262 U. S 731, 43 Sup. Ct. 607 (1923).

Recent legal actions. Up to April 29, 1940, the Department of Justice had brought 540 cases to enforce the antitrust laws; 129 of these, however, were instituted from 1932 to 1940. From 1914 to 1923, 18 lawyers were engaged in the Government's antitrust work; in fact, in 1933, only 18 attorneys were so employed, whereas in 1940, the legal staff included approximately 175 attorneys.

Recent actions taken by the Department of Justice, according to the Assistant Attorney General, have clarified the antitrust laws by securing Court opinions which bring within the law professional organizations, labor organizations, and those handling agricultural products. On the contrary, it is pointed out that, of the scores of cases recently initiated, the Supreme Court has not rendered an opinion in an important case. Thus associations have not received any new judicial guideposts.

Trade associations, professional organizations, labor unions, individuals, and corporations have been indicted under proceedings initiated by the Department of Justice. A number of consent decrees have been entered involving associations in such fields as paper containers, lumber, tile, and local contracting. While these decrees do not constitute a judicial pronouncement, reference may be made to such prohibitions as:

(1) Limiting production to predetermined quotas.

(2) Formulating or taking part in any plan for the prorationing of business, or the equable sharing of business, the purpose or effect of which is to limit production.

(3) Determining the volume of business of manufacturers for the purpose of establishing quotas.

(4) Collecting or comparing data respecting production, sales, orders, shipments, or deliveries for the purpose of determining whether manufacturers have adhered to or are adhering to quotas.

(5) Distributing production, shipment, or price data in such form as to indicate that a manufacturer is or is not adhering to quotas.

(6) Discussing at meetings of manufacturers or elsewhere, or by correspondence or otherwise, production, shipment, or price data in such form or manner as to indicate that a manufacturer has exceeded any such quota, or that it should limit present or future production so as to come within any quota.

(7) Examining or auditing the production, shipment, or price records or accounts of manufacturers for the purpose of securing adherence to quotas.

(8) Allocating or refraining from soliciting customers of manufacturers, or allocating markets or marketing territories.

(9) Fixing or maintaining prices.

(10) Promoting the use of an estimating manual or any other handbook or device for the purpose of fixing or maintaining prices.

(11) Using or promoting the use of premeditated prices for material.

(12) Examining or auditing production, shipment, or price records for the purpose of fixing or maintaining prices.

(13) Compelling manufacturers to submit to trade associations copies

of invoices or to identify any customer account in connection with the submission of invoices.

(14) Aiding or abetting any program to limit or otherwise control production.

(15) Operating a bid depository designed to fix prices or limit production.

(16) Agreeing to limit employment to those who are members of the association or otherwise discriminating against nonmembers.

(17) Maintaining a company for the purpose of entering into a nonprofit business with a view to driving out of business those who purchase direct from manufacturers or dealers who are not members of an organization.

(18) Distributing among all of the defendants the profits from commercial work done by any of them.

(19) Exchanging with each other, with the effect that competition in bidding is restricted, any information regarding quantity of materials and labor and the cost thereof, so that each might be able to calculate in advance of submission the bid to be submitted by others.

(20) Adding to bids arbitrary noncompetitive percentages of the total bid for the bidder's overhead and net profit, such percentages being fixed in advance by two or more defendants.

(21) Promoting any plan or policy designed to control channels of distribution or from combining to restrict the sale of products of any particular classes or types of trade.

Under its established procedure, the Federal Trade Commission has issued orders against those engaged in practices involving restraints of competition. During 1939, 23 complaints were filed against trade associations or business groups. This is more than the commission filed during any one of the 4 years immediately preceding. The agreements or understandings involving the restraint, suppression, or elimination of competition, cited in the orders issued by the Federal Trade Commission in 1939, dealt with such subjects as price control, customer or supplier control, division of territory, and collusive bidding.

Congress, over a half a century ago, incorporated into statute certain common-law principles relating to "restraints." Some types of actions by businessmen were recognized as matters of public concern The passage of the Sherman Act in 1890, of the Federal Trade Commission and Webb-Pomerene Acts in 1914, of the National Industrial Recovery Act in 1933, of the Robinson-Patman Act, of numerous state fair-trade acts, and of other legislation constitutes evidence that legislative bodies have given greater consideration to business practices in the last decade than in the first quarter of the century.

Undoubtedly, the depression, including the many problems arising therefrom, occasioned greater interest in these subjects. Aggrieved interests represented by competitors, buyers, sellers, labor, and so-called "consumer groups" each desired relief from the existing order.

The early cases arising under the Sherman Act generally involved only

one business concern. Many cases recently centered under the act involve a large number of concerns in the same industry. The unprecedented activity during the past 2 years arises, not from any change in the 50-year old Sherman Act, but from the fact that the personnel of the agency charged with the act's enforcement has been increased to approximately eight times the size which it has averaged during the preceding 15 years.

Congress has made a number of exceptions to the Sherman Act, but in most cases, it has increased rather than diminished the controls or the medium through which the public interests will be protected. Public authority has been created by special statute to impose the public interest upon motor carriers, railroads, and shipping. While such changes represent departures from the competitive principle, which many students believe constitutes a system of regulation more effective than the Government could devise, they embody ideals for economic justice.

As the preparedness movement encounters greater difficulties, it is conceivable that additional exceptions will be instituted. But Government supervision and regulation will accompany any such change.

Problems Confronting Trade Associations

As heretofore mentioned, trade associations will assume new duties in connection with the national defense program. Some of these new activities may become continuing parts of an association program. It is impossible to forecast the demands that will be made upon associations as this program develops, but it is evident that, as the problems confronting industry increase in intensity and scope, the trade association will devote more and more attention to them.

Nongovernmental business will continue to represent the major business activity in most fields. Problems arising thereunder will continue to require the consideration of trade associations. Business organizations may also be confronted with more active interest on the part of public authorities tending toward some form of regulation. Proposals for the registration, licensing, or control over association activities will continue to be made. The President of the United States, in his message to Congress on April 29, 1938, in enumerating a series of subjects proposed for consideration by the Temporary National Economic Committee, said:

> Supervision and effective publicity of the activities of trade associations, and a clarification and delineation of their legitimate spheres of activity which will enable them to combat unfair methods of competition but which will guard against their interference with legitimate competitive practices.

The author of *Trade Association Survey*[16] expresses the opinion that "it would be desirable to give to some agency of the government the definite responsibility for developing a body of facts that would permit a discerning appraisal of antitrust policy." The author also expresses

[16] Pearce, *op. cit.*

the opinion that the function of such an agency, with reference to trade-association statistics, "might include, in the first place, the establishment of standards for the dissemination of trade association statistics to interested parties in the trade other than participants in the reporting plan—whether competitors, customers, or suppliers." It was also suggested that the agency might have the power of subpoena and the authority to issue licenses on a revocable basis to associations in or affecting interstate commerce.

On the other hand, many students of trade associations believe that the remarkable growth in number and activity of trade associations is caused by the lack of rigid governmental restrictions. The Chamber of Commerce of the United States, at its annual meeting in 1940, adopted the following resolution:

> Business has long maintained trade associations as a means of carrying on important functions in the interest of business and the public. The efficiency of management has been furthered, the extension of markets promoted, the stabilization of employment fostered, the establishment of fair competition advanced, and the rights of industry upheld through the proper operation of trade associations representative of their fields.
>
> The benefits which have accrued from such cooperative work have been due in part to the flexibility, the voluntary character, and the freedom from special forms of governmental control of trade associations. Such conditions should be preserved, in order that trade associations may continue to extend their usefulness to their fields of business enterprise and to the public. They are now advancing a wide range of activities in keeping with the highest public interest and extending from programs for training employees for their advancement to promotion of scientific and technical research productive of better goods at lower costs. The Department of Commerce in the utilization of the data it has collected has a great opportunity to advance the whole trade association movement by making clear the public benefits that are now being realized and the still greater benefits in prospect for the future.

Irrespective of particular types of legislative proposals that may be made, it is evident that the economic significance of trade associations is becoming recognized by an increasing number of individuals representing the Government and educational institutions as well as by businessmen. More information is currently being distributed with reference to trade associations. In this connection, a number of agencies have been helpful.

United States Chamber of Commerce.—Trade Association Division. Trade and industrial organizations have been affiliated with the Chamber of Commerce of the United States since its organization in 1912. For over a quarter of a century, it has worked with trade associations in the development of sound economic policies. In 1928, the Trade Association Department was established to give further emphasis to the work of trade associations. The formation of trade associations, problems incident to their management and operation, and the development of policies with respect thereto constitute some of the functions of this division Conferences with officers, committees, and staffs of trade associations are

held with respect to organization, management, and operation. Addresses are made at meetings on the work of trade associations and the problems confronting business. Special studies are made with respect to organization structure, operation, and activities of trade associations. The division thus serves as a clearing house of information on trade-association practice and achievements.

American Trade Association Executives. Executives of trade associations, in 1920, organized the American Trade Association Executives, which provides a common ground for men and women employed by different types and kinds of associations to share in the interchange of information and opinion. The annual and semiannual meetings represent forums at which management and other subjects of interest to trade associations are discussed.

In some of the larger cities, local organizations of trade-association executives exist. Most of these groups hold monthly meetings.

National Institute for Commercial and Trade Organization Executives. The National Institute was organized in 1920. It is sponsored by the American Trade Association Executives, the National Association of Commercial Organization Secretaries, Northwestern University, and the Chamber of Commerce of the United States. It was established for the purpose of helping commercial-, trade-, and industrial-organization executives to improve their technique. The Institute meets for one week, in August of each year, at Northwestern University. A definite schedule of courses has been developed. Executives completing a 3-year course are given a certificate. Textbooks have been issued, and considerable material has been made available to trade-association executives and students of trade-association work.

National Industrial Council. The National Industrial Council, an affiliation of the National Association of Manufacturers, includes in its membership some local and state industrial associations and national trade associations.

Department of Commerce. The United States Department of Commerce, in recent years, has also given additional emphasis to the work of trade associations. A special section was created in the Bureau of Foreign and Domestic Commerce. Since 1913, it has issued several lists of business and professional organizations. Included in publications of the department are references to work of trade associations.

The collection and distribution of an increasing amount of information concerning the work of trade associations has created a better understanding of the true functions of trade associations. Many now recognize that a trade association

> . . . does not order, it advises. It does not coerce, it persuades. It does not issue mandates or even instructions. It uses only the moving eloquence of a reasoned appeal to the self-interest of its members. It does not tell its members what they must do. It tells them what, if influenced by a decent regard for their own interests, they will be glad to do. It assumes that its members are intelligent men, that they can think about the problems of their business and that, if the facts out of

which these problems arise are placed clearly before them, and if the significance of the facts is pointed out, a proper and profitable line of action will result.[17]

Broader functions recognized. Trade associations include the leaders in industry. These men are desirous of securing information that will enable them to increase their efficiency, reduce their cost, and expand their markets. They believe that business morality—ethical standards—is essential to the successful operation of business. Business leaders are willing to promote coöperatively those practices and principles which are essential to the maintenance of good business from the standpoint of permanency, profits, and public interest.

Trade associations are being utilized in more ways by more people because they provide a means of reaching, in an understandable manner, an entire industry. They are being upheld by educators, philosophers, and students because they protect and promote the principles which are a part of our economic, social, and political system. Trade associations are democratic in character; they recognize the rights of the individual and defend free and fair competition. They promote initiative and oppose forces which threaten to stifle the development of business. In their efforts to find new products and new uses for existing products, they are calling upon the best technical skill in the industry. The specialists in the marketing and merchandising fields join in efforts to extend the markets of each industry.

The trade association of 1940 represents the evolution of the organizations created before the turn of the century. But it is pursuing more activities to aid business in more of its problems than ever before. Industrial leadership, business statesmanship, and principles of the American economic system are being sustained and developed by trade associations. Imbued with their responsibility to the public, trade associations will become an increasingly important agency in dealing with governmental matters as well as with the internal problems confronting each industry.

[17] Meade, "Lawful Restraint of Trade Through Education," in *The Annalist* (August 9, 1929).

INDEX

A

D

G

O

U